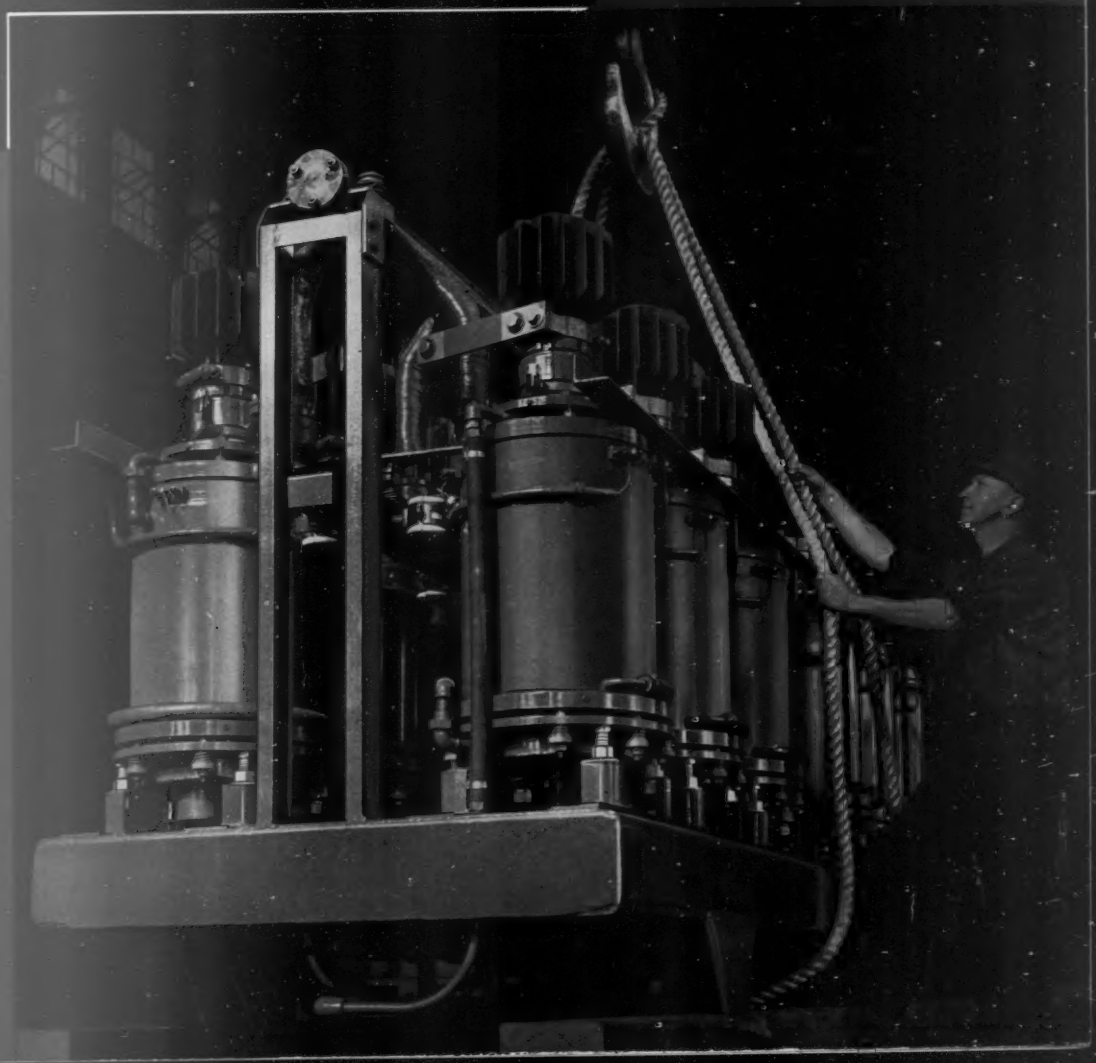
ALLIS-CHALMERS

ELECTRICAL REVIEW

September • 1942



HOW AN ENGINEER SAVED OVER 75,000 LBS. OF COPPER!

HELPING TO INCREASE production in war-busy industrial plants, Allis-Chalmers 5/8% Step Regulators, like this 375 kva, 12,000 volt, three-phase unit, are in use all over the country.

Improves Motor and Lamp Performance in New Armament Plant . . . Saves Thousands of Pounds of Copper and Vital Man-Hours for the Victory Effort . . . by Installing an Allis-Chalmers 5/8% Step Regulator!

A NEW armament plant was going up on the outskirts of a midwestern city. Power was to be supplied by an existing 5½ mile, 12,000 volt, Y-connected line already carrying 2100 kva. But the No. 0 copper wire was too small to handle the added 1500 kva load without excessive voltage drop at the end of the line.

One of the many solutions that occurred to the Planning Engineer was to put up heavier wire — 400,000 cm on the three conductors to keep voltage variation within 10%. But this would require 78,500 extra pounds of copper* and hundreds of man-hours.

Other possibilities included moving the substation, increasing the voltage, tying in with another line, or building a new line. But, weighing all factors, he decided to install a feeder voltage regulator to maintain uniformly high voltage.

The regulator required only a few hundred pounds of copper . . . a fraction of the man-hours to build. What's more, the regulator takes care of fluctuating source voltage . . . corrects for reactance as well as resistance drop . . . permits better motor and lamp performance.

And, when they actually bought the regulator, they selected a 375 kva, 12,000 volt, 3-phase Allis-Chalmers AFR, the regulator with *proved on-the-line performance.*

Check the reasons (at right) why engineers choose Allis-Chalmers Regulators. For complete information write for Bulletin B6056. Allis-Chalmers, Milwaukee.

*Weight of three 5½ mile lengths of 400,000 cm wire = 16.5 x 1220 x 5.28 = 106,300 lb of copper. Weight of salvaged No. 0 wire to be credited — 27,800 lb.

A 1521

REASONS WHY ENGINEERS CHOOSE ALLIS-CHALMERS 5/8% STEP REGULATORS!

1 **Closer Regulation!** 5/8% half-cycling steps plus "Feather-Touch Control" permit band width settings within ±5/8 of 1%.

2 **Longer Contact Life!** Not a single contact has ever been replaced on an Allis-Chalmers Regulator due to deterioration under normal operation.

3 **Lower Exciting Current!** Need only 1/3 the exciting kva required by older types of regulators.

4 **Increased Dielectric Strength!** Unit construction eliminates 78 bolted connections between compartments.

5 **Minimum Maintenance!** No holding or braking devices. Complete oil-immersion of all moving parts means there's nothing to lubricate.

When On-the-Line Performance Counts... Count On

ALLIS-CHALMERS

MILWAUKEE · WISCONSIN

ALLIS-CHALMERS

ELECTRICAL REVIEW

CONTENTS

Pioneering in Electronic Engineering 5
O. K. MARTI

Standardized for Saving 14
R. W. BEARD

Blowing Transformer Ratings Upward 20
K. P. WIEDERKEHR

New Equipment 24

Power for Portland Cement, Part II 25
J. M. WOLFE

Make Your Mark! 31
D. JOURNEAUX

What's the Answer? 34

★

Vol. VII . . . . No. 3

September, 1942

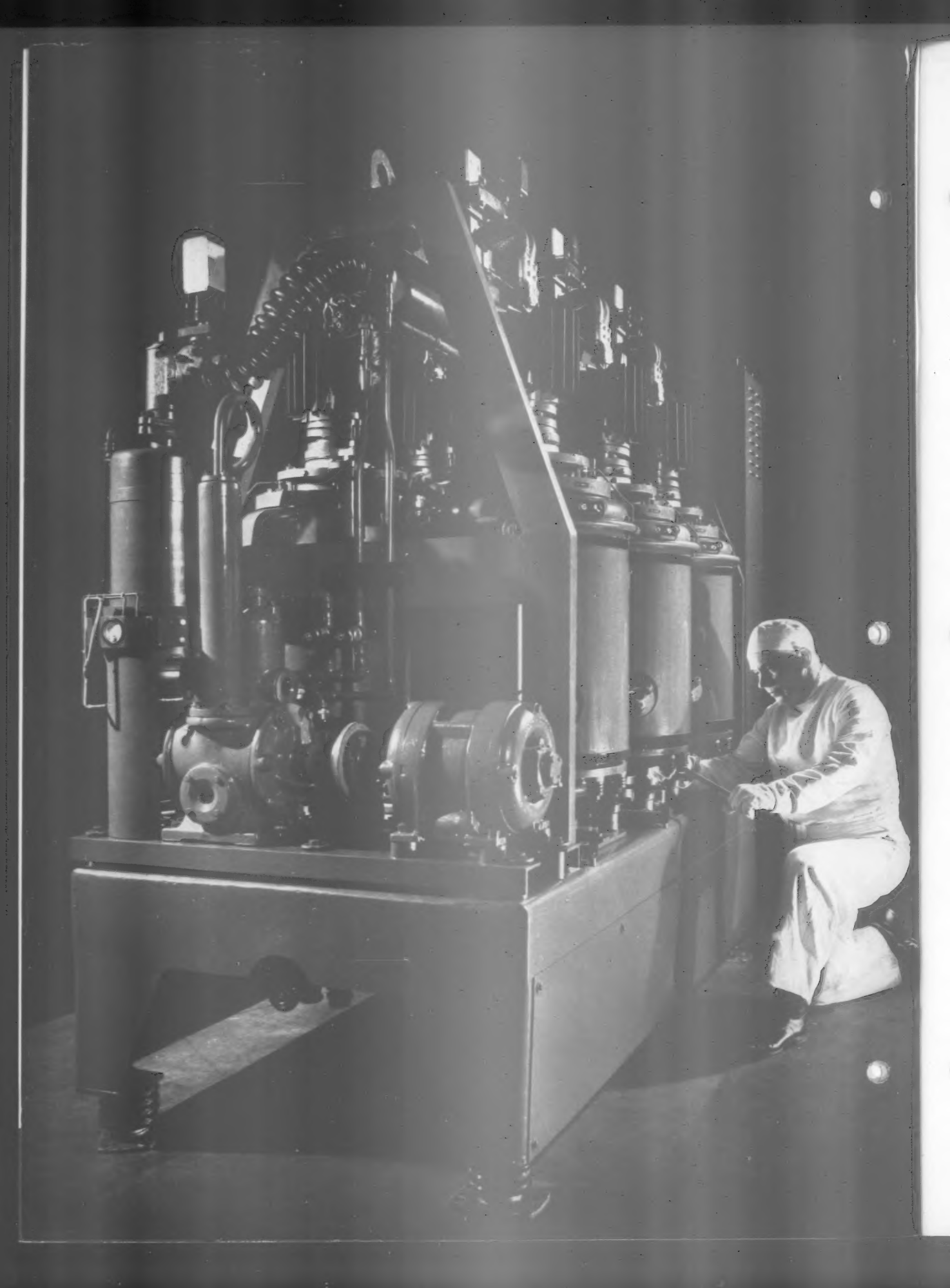
Allis-Chalmers
Electrical Review

Board of Editors: R. S. Fleshiem, L. H. Hill, G. J. Callos. Executive Editor: D. S. Mortensen. Production Editor: F. C. Alexander. Associate Editors: B. C. Halsted, O. Keller, H. Oman, L. Teplow. Photography: M. H. Zielke. Circulation: H. A. Reinhard.

Issued quarterly. Subscription rates: U. S., Mexico and Canada, $2.00 per year; other countries, $3.00. Address Allis-Chalmers Electrical Review, Milwaukee, Wisconsin.

Printed in U. S. A.

Copyright 1942 by
Allis-Chalmers Mfg. Co.



PIONEERING IN ELECTRONIC ENGINEERING

Large blocks of power conversion from a-c to d-c and interconnection of a-c systems of different frequencies . . . the versatility of the mercury arc rectifier is just beginning to be put to work.

O. K. Marti, **Consulting Engineer**

RECTIFIER DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

Some ten years ago the importance of static electronic power conversion equipment became fully recognized, and a great deal of attention was given to a long-range research program to introduce the electrically grid-controlled rectifier for conversion of large blocks of alternating-current power into direct-current power for electrochemical plants and also for conversion of alternating-current power of one frequency into power of another frequency as required in the industrial and railway fields. As a result of this work the above investigation culminated in the installation of the largest concentrations of electronic a-c to d-c power conversion equipment ever attempted and, at present, in undertaking the conversion of a large block of 25 cycle power into 60 cycle power and vice versa in a large steel mill.

Control of large blocks of rectified power

Although rectifiers had been successfully used for several years in American and Canadian plants for electrolytic production of chlorine-caustic, hydrogen-oxygen, zinc and cadmium, up to 1937 no installation had been made for the production of aluminum on this continent, where the requirements imposed on the converting equipment were far more severe than in other service because of the large amount of power concentrated in one substation. Such large installations as would be required for modern reduction furnaces foreshadowed many new problems.

In order to make the rectifier a useful converter for such applications it was necessary to have a reliable voltage control which would permit keeping the current at certain values, regardless of the change in resistance of the cells or furnaces, and would furthermore permit starting up the plant at the required voltage and with the proper steps.

AT LEFT: This six-tank, single-anode mercury arc power rectifier unit, with its built-on control cabinet and evacuating equipment, has a continuous rating of 2500 amperes for steel mill service.

More than ten years ago extensive tests were carried out, in collaboration with a large midwestern utility, on a then new method of regulating the output voltage of a 3000 kw, 600 volt power rectifier by means of electrically energized grids. This method utilizes the fractional or chopped wave system and has been described in detail in a number of papers during recent years. Its successful operation in this first commercial installation speedily led to its introduction in a number of other large rectifier plants.

The above-mentioned rectifier, equipped with electrically energized grids permitting such a control, was installed in a substation supplying power to a city traction system. This unit was arranged for manual and automatic voltage control (rocking contact type voltage regulator).

After a sufficient length of time had elapsed to prove, beyond doubt, the fact that the electrically energized grids of even the largest power rectifiers could maintain the control action under all service conditions (system short circuits and arc backs), grid control was introduced in an electrolytic installation for the first time in 1934.

In connection with this first installation, it was found necessary to filter out any reactions of power circuit distortions on the grid supply voltage wave. For this purpose a wave filter consisting of a small reactor and condenser in each phase of the three-phase grid supply was developed and gave satisfactory service. (See Fig. 5, Filter.)

This installation consisted of one double-tank, multi-anode rectifier unit, and the substation was later enlarged by the installation of additional rectifier units. Other rectifier installations in electrolytic plants of similar capacity followed, laid out along the same engineering lines.

On the basis of the good operating experience obtained with all these plants, where a number of multi-anode rectifiers were operating in parallel, it was possible to meet the requirements of electrolytic cells hav-

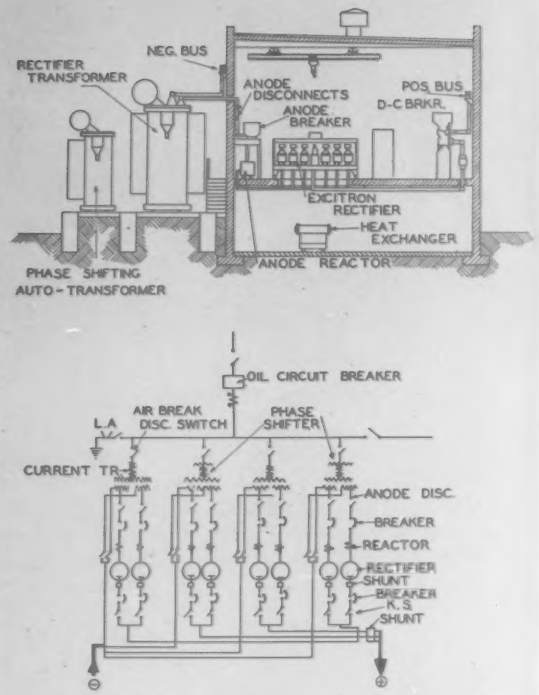


Fig. 1—Layout and schematic diagram of typical electrolytic installations.

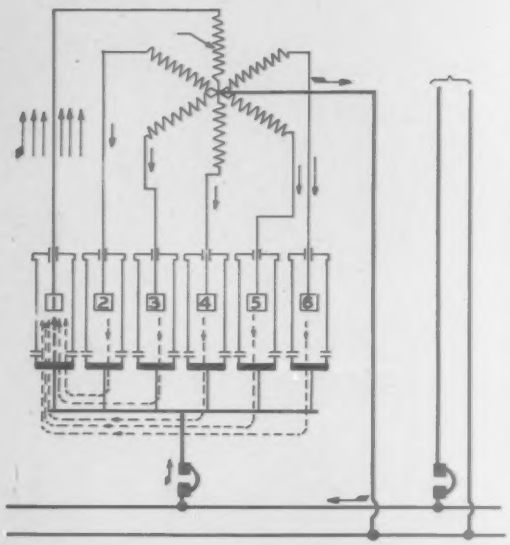


Fig. 2—Diagram showing flow of currents during arc-back.

ing much higher current capacities than hitherto employed and also to meet, without unusual risk, direct-current requirements as great as 40,000 to 50,000 amperes at 625 to 650 volts, required by large-scale aluminum reduction plants. Several such rectifier plants went into operation in 1938. For a layout of a typical large plant of recent design, see Fig. 1.

When laying out the first of these plants, where 20 rectifiers had to operate continuously in parallel on a common direct-current bus, many new problems naturally presented themselves, and some of them are described below.

Arc-back phenomena in power rectification

In an installation having ten or more large-capacity rectifiers of twelve anodes each, rectifying action takes place over 25,000,000 times every hour. The importance of great reliability of the rectifying action of the mercury valve (freedom from failures of valve action, called backfires or arc-backs) is therefore self-evident, and primary attention was consequently given to this problem.

If a failure of the valve action occurs, leading to an arc-back (see Fig. 2)—i. e., when a cathode spot is formed on an anode—current will flow not only from the cathode to the faulty anode, but also from the other anodes in the same rectifier to the backfiring anode, or in the case of single anode rectifiers, from the cathodes of the several tanks to the faulty anode, as determined by the potential difference existing between the various electrodes.

From Fig. 2 (heavy line) it is evident that such a disturbance results in effectively short-circuiting the a-c circuit through the transformer and rectifying valves, the rate of rise and the final value of the current being then limited only by the transformer impedance and by the voltage drop in the rectifying arc.

The high currents flowing during a backfire, if repeated too often, may ultimately damage the transformer not only by their heating effect, but also by the mechanical stresses produced by their electromagnetic action. The only remedy for such a disturbance is to open the rectifying circuit. This can be accomplished by opening the primary and the d-c breakers. If particularly speedy clearance of the fault is desired, it may also be effected by opening all the anode circuits (secondary phases of the transformer), using the latest development in anode breakers.

It is desirable that the individual sections of the transformer windings be so arranged that a high leakage reactance opposes the flow of backfire current. It is especially necessary when more than one rectifier is connected to one transformer, and where a number of such units are connected in parallel, to reduce the magnitude of the backfire currents as much as possible.

Figure 3 shows the special coil arrangement which produces this effect in a typical rectifier transformer

having two windings for supplying two double-six phase rectifying systems, each rated 2750 kw at 600 volts.

Protection by high-speed grid blocking and anode breakers

With modern breaker and grid blocking equipment, interruption of an arc-back can be accomplished in a fraction of a cycle, as will be seen below. In the large rectifier installations this problem was met by using high-speed cathode breakers, or six-pole high-speed anode breakers, together with high-speed grid blocking. The diagram of connections and the equipment used for such an installation are shown in Fig. 5. By such means it was found possible to interrupt any disturbance, short circuit, or backfire, before the forward or reverse current could rise to more than five times its normal value. The grid blocking may also be made to function on all units in case of a bus short circuit and, therefore, may act also as a back-up protection for the d-c switchgear.

The mode of operation of this type of grid protection is evident from Fig. 5. In case of a backfire, a voltage impulse produced by the differentially-connected anode current transformers releases the tubes 77G and 77T, which suppress the a-c components of the grid voltage and apply a blocking negative potential to the grids of the power rectifier, thus preventing the anodes from firing. In normal operation, when the currents of parallel anodes are balanced, there is no voltage applied through the small disc type rectifier S-3, and tubes 77G and 77T are blocked. The current transformers are mounted on the anode leads at the terminal board as can be seen in Fig. 4, which also shows the anode breakers and anode reactors.

The speed of such a system is best exemplified by the field test oscillogram shown in Fig. 6, wherein the grid blocking equipment operated in 1/10 cycle, the current was limited after 1/3 cycle and the backfire current was completely interrupted in about ½ cycle. This speed makes it unlikely that more than two pairs of anodes will feed into the backfiring anodes since the firing of the "later" anodes is prevented by the negative potential applied to their grids. In other words, should anode 1 in Fig. 5 fail to rectify when becoming negative, only anodes 2-8 and 3-9, next in firing sequence, could feed into it.

A similar action may be obtained by the introduction of a six-pole anode breaker (see Fig. 5) which will open the anode circuit to the secondary phases of the transformer and which will also prevent the sound anodes from feeding into the backfiring anode. Such a six-pole anode breaker not only prevents the sound anodes from feeding into the faulty anode but also interrupts the current flowing from the parallel-connected units. These anode breakers have been developed today to such perfection and for such high opening speeds (1/3 cycle) that the grid blocking equipment is actually not required in most applications.

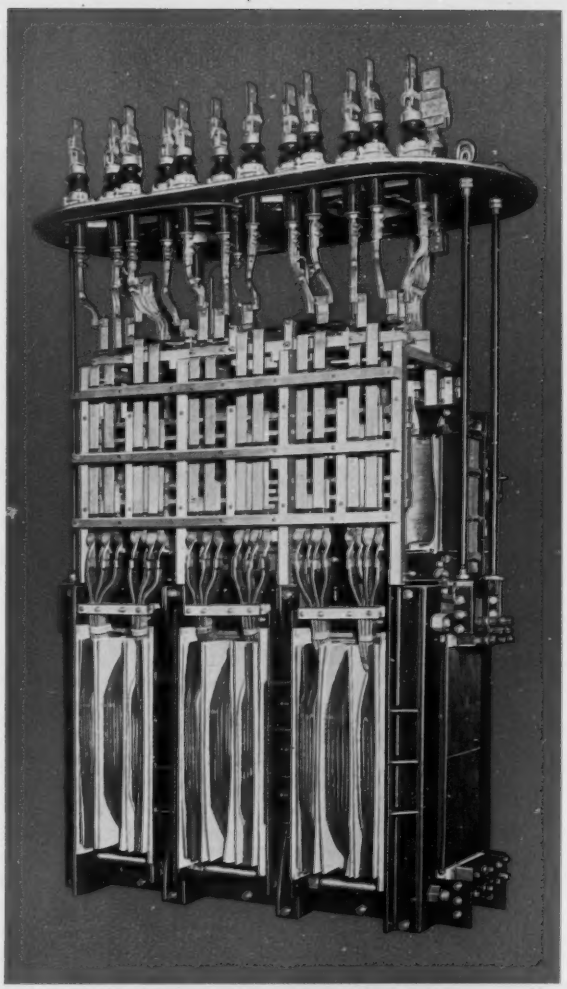


Fig. 3 — Coil and anode lead arrangement, with tap changers, of a 6910 kva transformer that will serve two twelve-anode rectifiers.

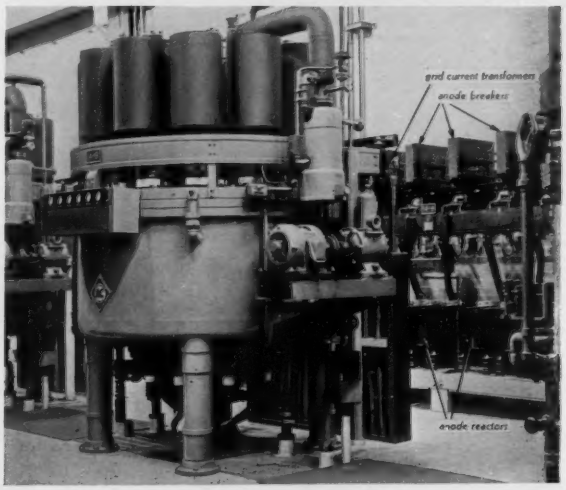


Fig. 4 — In this installation can be seen anode leads with grid-blocking current transformer, anode breakers and anode reactors.

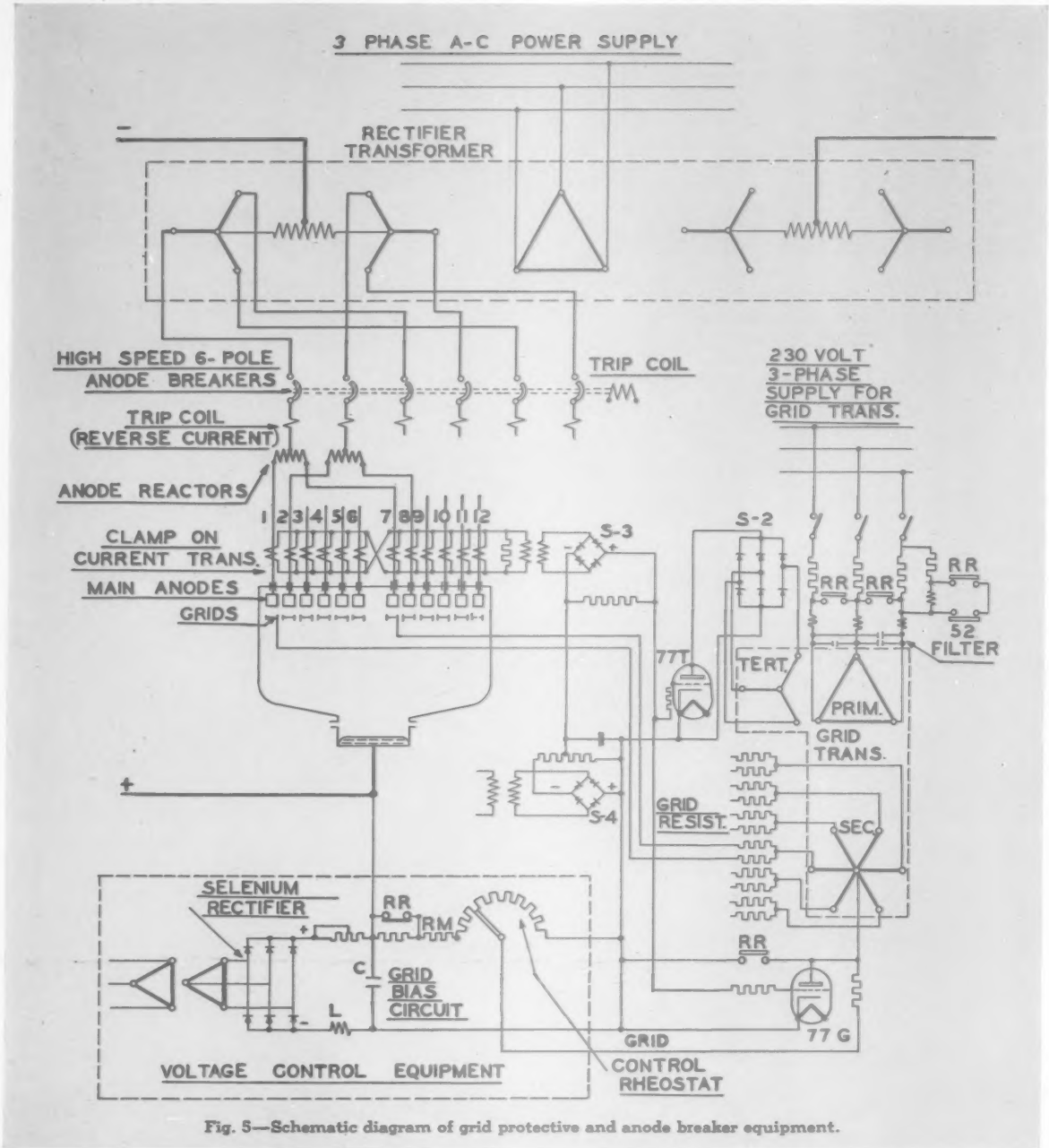


Fig. 5—Schematic diagram of grid protective and anode breaker equipment.

In plants using single-anode rectifiers, as shown on page 4, automatic grid blocking could be supplemented by excitation extinction. Since the main arc in single anode rectifiers extinguishes every cycle, a cathode spot has to be maintained or re-established every cycle by the excitation anode; therefore, the main arc can be prevented from firing if the cathode spot is extinguished or prevented from being re-established by interrupting the power supply to the excitation anode.

Figure 7 shows a diagram of connection and Fig. 10 a cross section of one type of single-anode rectifier unit. The cathode spot is maintained by means of the anodes a_1, a_2 after it is established by the ignition devices i_1, i_2 ..... By opening relay contacts b_1, b_2 the excitation of the tanks is extinguished. Should any kind of disturbance cause operation of relay 3, the cathode spots would be instantaneously extinguished, and the main anodes would fail to reignite. The coil of relay 3 can be energized from a primary

current transformer, as shown in Fig. 7, or from clamp-on current transformers connected to the anode leads, as shown in Fig. 5.

Neither this scheme nor the blocking of the grids, however, prevents the flow of backfeed current from other converting equipment operating in parallel. If this equipment consists of grid controlled rectifiers, then the backfeed current can be limited by their respective backfire protective devices.

Reduction of wave distortion in large rectifier plants

In connection with large plants another phenomenon had to be taken care of; viz., it was necessary to find ways and means to reduce the distortion of the wave shape of the power supply caused by the valve action of the rectifier.

The resulting wave on the a-c input side consists of a fundamental sine wave upon which are superimposed a number of harmonics of different frequencies, magnitudes and phase relationships. Several methods were investigated in an extensive research project carried out in collaboration with telephone companies by means of miniature sets. The best results were obtained by shifting the phases of the rectifier units with respect to each other so that the result, with respect to the station as a whole, is a multiple-phase system.

In all of the transformer connections used to secure six-phase operation of a rectifier when supplied from a three-phase source, there is a 60 deg phase relation between the voltages applied to the anodes firing consecutively. Consequently, the lowest-order harmonic component appearing in the d-c voltage wave is the sixth (360 cycles for a 60 cycle supply system), and the corresponding components in the a-c supply are the fifth and seventh harmonics (300 and 420 cycles). In the case of a 12-phase rectifier the a-c harmonics are the 11th, 13th, 23rd, 25th, etc., which have frequencies of 660, 780, 1380, 1500, etc., cycles.

The output voltage and current of a rectifier also contain superimposed ripples, whose magnitudes depend on the reactance in the circuit, while their frequencies depend on the frequency of the supply and the number of phases. Large electrolytic installations, where the d-c power is fed to the cells over very short lines, present no d-c coordination problems, as rectifiers feeding a trolley system sometimes do.

On the other hand, on account of the large percentage of the total power taken from the a-c supply system by the rectifiers, the amount of primary system wave distortion is correspondingly larger, and even a 12-phase arrangement will not assure telephone service free of interference.

Therefore, the a-c harmonics were still further reduced in large installations by the introduction of phase-shifting auto transformers on the primary sides of the rectifier transformers. These displace the relative phase positions of some of the rectifier units so as to increase effectively the number of phases in the installation from six to 30 or even more, in this way eliminating all the a-c harmonics of orders below the 29th and all the d-c ripple harmonics below the 30th, and improving the power factor appreciably.

In well-balanced installations, harmonic components in the frequency range from 300 to 1140 cycles have been reduced in ratios varying up to nearly 100:1 by phase multiplication using phase-shifting auto transformers. Where additions are made to rectifier installations of the multi-phase arrangement, the number of phases can be increased by coordinating the design of the new units accordingly.

Figure 8 shows in the foreground one of these phase-shifting transformers, which are auto transformers with 1:1 voltage ratio. Fig. 9 shows the smoothing effect on the line current of a 30-phase system because of the elimination of the lower order harmonics prominent in a 6-phase and even in 12-phase systems.

Excitron — single-anode rectifier

Besides the many improvements and developments applying to new applications of rectifiers, their protection, etc., another major development was carried out—a single-anode power rectifier which, to distinguish it from the multi-anode type, is designated as the Excitron. Instead of having all the anodes in one vacuum chamber, the Excitron consists of factory-assembled groups of relatively small vacuum tanks, each containing a single anode and its individual cathode. The tanks, which are externally cooled by water, are generally mounted in groups of six or twelve on a structural steel frame. This frame also supports the vacuum pumping equipment which is connected to the tanks through a vacuum pipe manifold. The arc ignition and control equipment may also be mounted and wired on this frame (see page 4).

The anode assembly is shown in Fig. 10. It will be seen that this is similar to the design used in a multiple anode rectifier. The anode itself, its insulation, the control grid, and other parts are of the same type and size as are the corresponding parts of a multiple-anode rectifier having a rating similar to that of an Excitron unit of a suitable number of tanks.

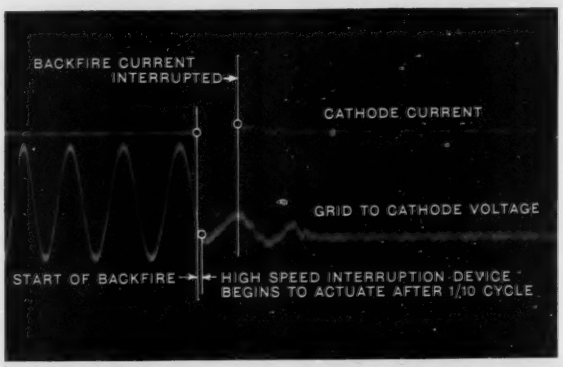

BACKFIRE CURRENT INTERRUPTED
CATHODE CURRENT
GRID TO CATHODE VOLTAGE
START OF BACKFIRE
HIGH SPEED INTERRUPTION DEVICE BEGINS TO ACTUATE AFTER 1/10 CYCLE

Fig. 6 — Oscillogram shows speed of backfire current interruption.

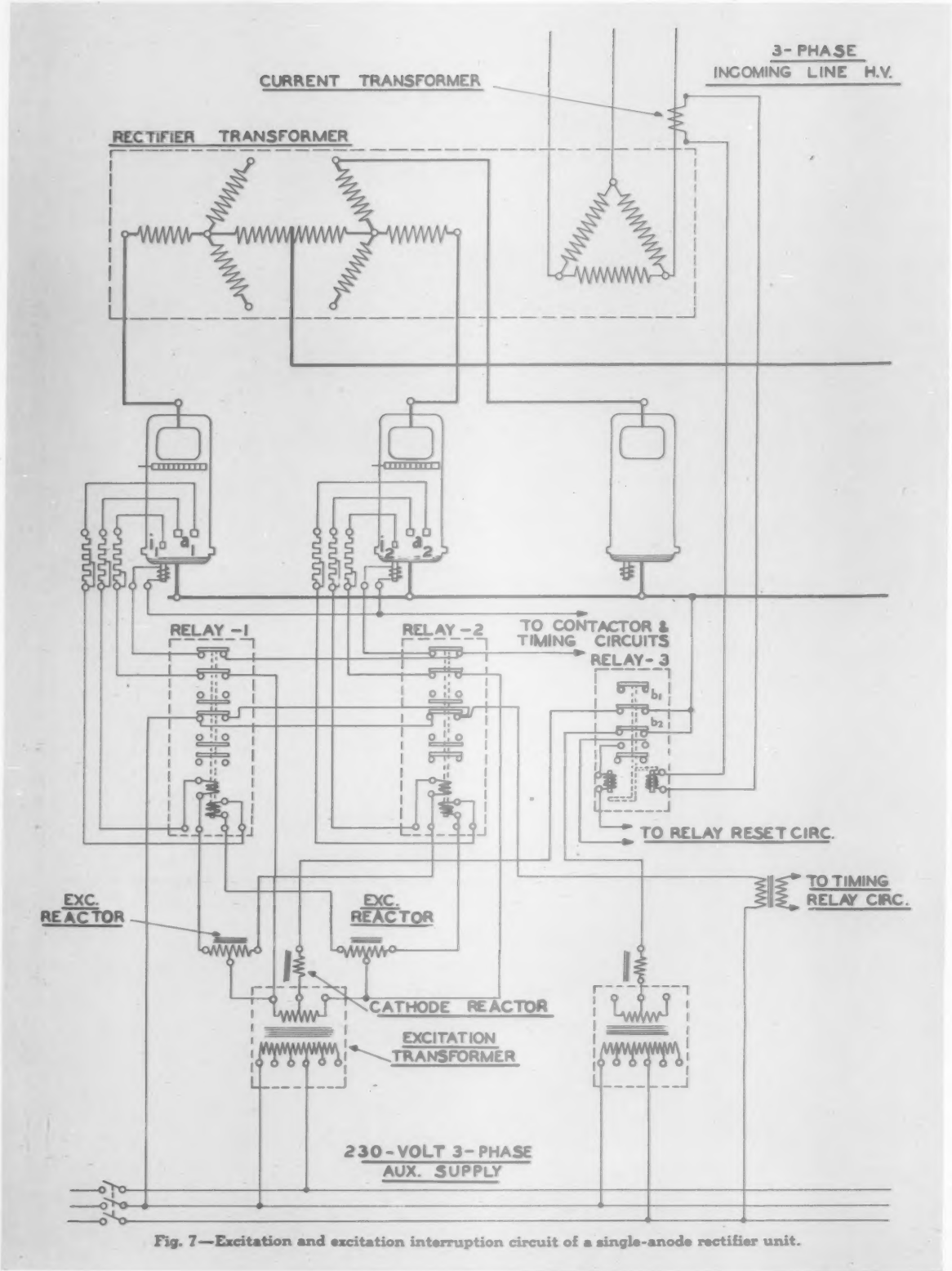


Fig. 7—Excitation and excitation interruption circuit of a single-anode rectifier unit.

Because of the closer spacing between an anode and its associated cathode than in the multi-anode type of rectifier, the voltage drop in the mercury arc is reduced and as a result the efficiency of the Excitron unit is higher in the lower voltage brackets. Although this advantage is particularly pronounced at 250-300 volts, the Excitron rectifier is none the less equally adaptable for use at higher voltages. The improvement in efficiency is, however, not so pronounced at voltages in the neighborhood of 650 volts d-c. Possessing all the advantages inherent in a multiple-anode type rectifier, the Excitron unit also makes use of reliable and simple arc ignition and control devices. Since these auxiliary anodes are not immersed in mercury, and are not deleteriously exposed to the main arc, nor affected by impurities on the cathode surface, long life can be expected. From Fig. 10, showing a cross section of a tank, it can be seen that an excitation anode is located a short distance above the mercury cathode on the right hand side, and on the left hand side is an ignition electrode located close to the tank wall.

The ignition device shown mounted below the cathode, directly beneath the ignition electrode, functions by momentarily throwing a small jet of mercury from the cathode onto the ignition electrode. When the mercury jet collapses, it strikes a small arc which is at once picked up by the excitation anode similarly to the action of a multi-anode rectifier tank. A diagram of connection for the excitation and ignition circuit is shown in Fig. 7, using one ignition and two excitation anodes. The number of auxiliary anodes can be reduced by using one of the excitation anodes as an ignition anode as well, or by using d-c for excitation.

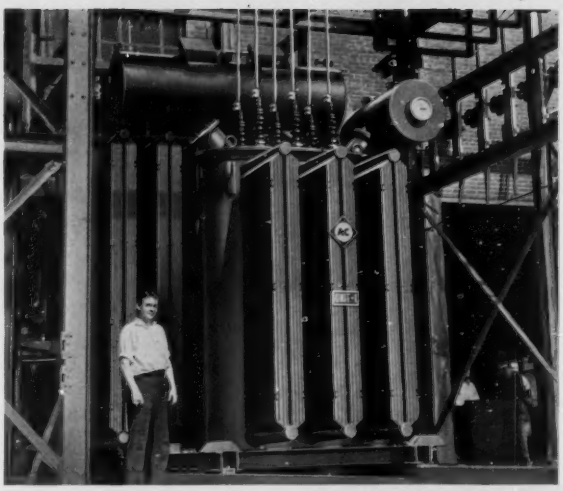


Fig. 8 — Phase-shifting auto-transformer in front of 5500 kw rectifier transformer in a large electrolytic metal reduction plant.

Each tank may also have one or more control grids mounted a short distance below each anode. The grids, although somewhat different in design, perform the functions as outlined above. See also Fig. 5.

Such single-anode rectifiers can readily be combined in groups of two, three, four, six, or twelve to provide single-phase, three-phase, four-phase, six-phase, or twelve-phase rectification on exactly the same principles as those employed for the multi-anode rectifiers.

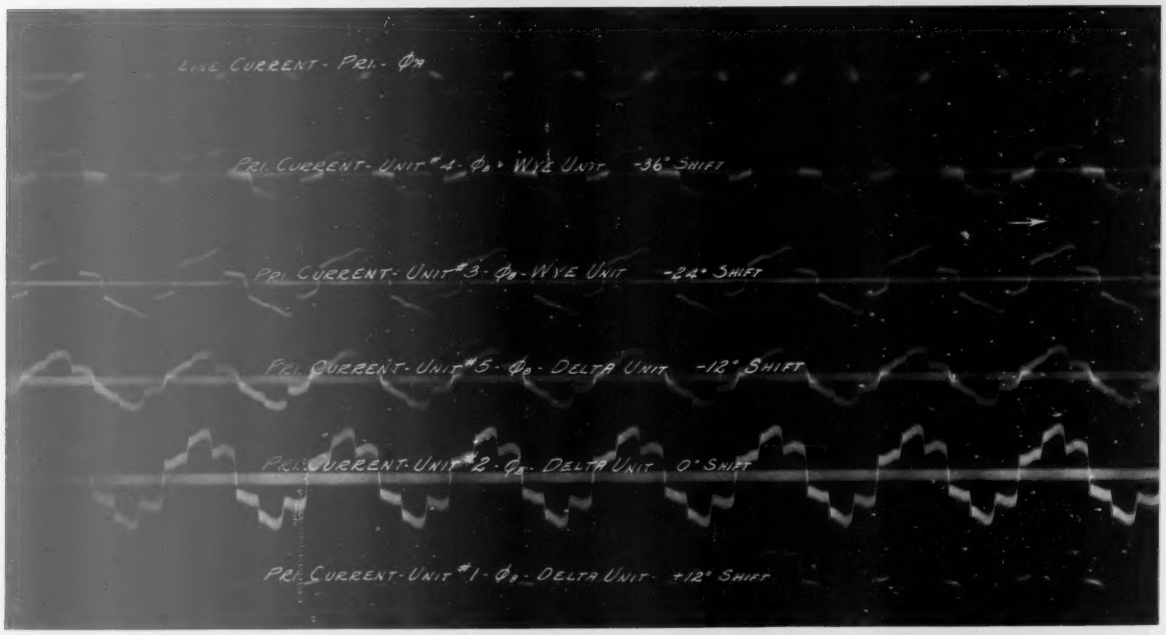

LINE CURRENT - PRI. - ϕ_T
PRI. CURRENT - UNIT #4 - ϕ_8 - WYE UNIT -36° SHIFT
PRI. CURRENT - UNIT #3 - ϕ_6 - WYE UNIT -24° SHIFT
PRI. CURRENT - UNIT #5 - ϕ_{10} - DELTA UNIT -12° SHIFT
PRI. CURRENT - UNIT #2 - ϕ_4 - DELTA UNIT 0° SHIFT
PRI. CURRENT - UNIT #1 - ϕ_2 - DELTA UNIT +12° SHIFT

Fig. 9 — These oscillograms demonstrate the smoothing effect on the line current of a thirty-phase rectifier system.

Previous experience applied

The experience obtained with the first three large electrolytic plants, where equipment delivering more than 100,000 amperes is paralleled, was such that the same practices have now been applied to other electrolytic plants having both multiple and single-anode rectifiers. All features introduced in these large plants have worked out satisfactorily during several years of operation. Full protection of all equipment was obtained during abnormal operating conditions, such as bus shorts, lightning interruptions, backfires, etc.

The starting of reduction plants can be accomplished quickly and with ease. The setting into operation of plants with cell loads of low starting back emfs can be accomplished without severe shocks to the supply system. Furthermore, the voltage control by grids not only simplifies the starting of these plants but permits quick and easy adjustment to suit varying cell conditions, etc.

The single-anode Excitron rectifier described above is also being utilized in large electrolytic installations requiring the paralleling of numbers of units and, because of its favorable efficiency, particularly at the lower voltages, is helping to effect the power saving which is always sought after and is especially important at this time.

Static power conversion from 25 to 60 cycles

Another field of application for grid-controlled rectifiers was also under constant investigation—the conversion of a-c power of one frequency to a-c power of another frequency. Preliminary investigations indicated that, from a practical standpoint, the best solution would be obtained with a conversion scheme wherein a-c is first changed into d-c and the d-c is then changed back into a-c of the required frequency.

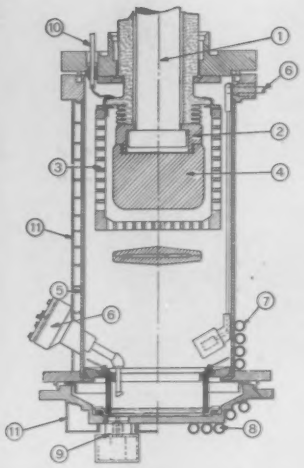


Fig. 10—Cross-section of single-anode rectifier.

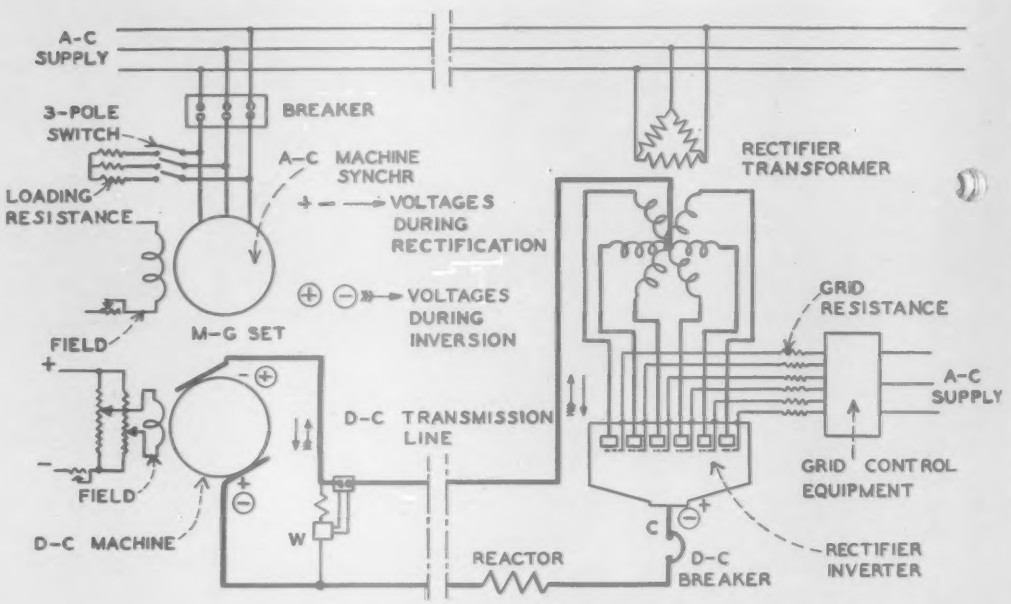


Fig. 11—Test circuit to demonstrate inversion.

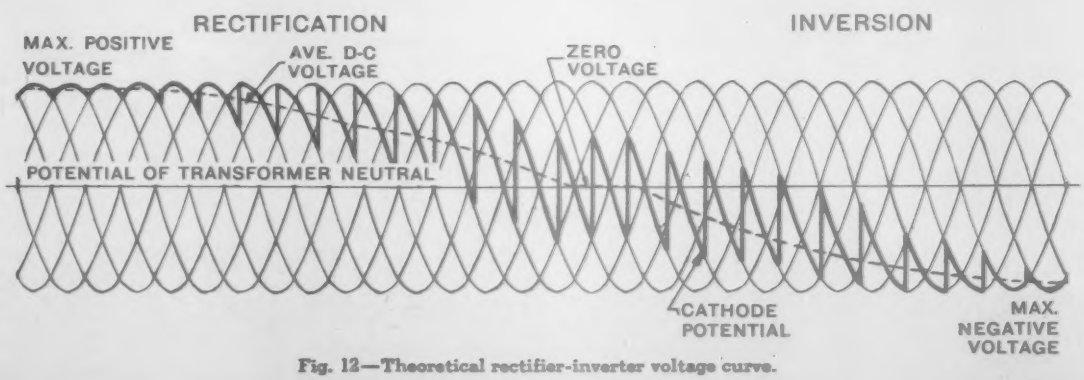


Fig. 12—Theoretical rectifier-inverter voltage curve.

The first step, that of converting a-c to d-c, was well explored, as can be seen from the first part of this article, but not the converse; i.e., inverting d-c into a-c power. Several small low-capacity inverting and converting units were developed for educational institutions, and extensive tests were carried out with a large rectifier-inverter set-up. One of these sets was designed for a medium voltage and another for a very high rectified d-c voltage.

Inversion demonstration and explanation

With the test set-up shown in Fig. 11, using only one rectifier-inverter, inversion of the d-c power, furnished by the d-c machine of a motor-generator set, into a-c power, which was fed back into a 2300 volt a-c system of relatively large capacity, was accomplished in the following manner:

The motor-generator set was adjusted to a synchronous speed of 1200 rpm at no-load by regulating the d-c output voltage of the rectifier with the grid-control circuit. The breaker between the a-c machine and the three-phase power line was closed to synchronize this machine with the supply system.

In order to accomplish inversion of power it was necessary to handle only small amounts of power in the grid-control circuit, which automatically retarded the firing of the anodes to the negative part of their voltage waves (see Fig. 12), and to reverse the field of the d-c machine by means of its potentiometer. This caused a reversal of power flow in the d-c circuit since the d-c machine was changed over to operate as a generator and supply power to the inverter, which fed the power in a-c form back into the 2300 volt, 60 cycle, a-c system.

Other tests were made using two 9000 volt d-c rectifiers to obtain data on rectifying and inverting a-c to d-c, and back to a-c.

The theory of inversion can be better understood by reference to the right-hand side of the voltage diagram of Fig. 12. If the anodes, instead of being allowed to fire during their positive half-cycle of voltage, are prevented from firing by the grid-control circuit until the negative half-cycle, the output voltage of the rectifier unit is automatically reversed. From the diagram for minus 75 percent voltage it is seen that each anode is released and carries current during the negative half-cycle, so that the cathode potential of the unit becomes negative with respect to the neutral of the transformer. If the anodes are prevented from firing until still later during their negative voltage wave, the inverted voltage is increased in value, as illustrated on the diagram, to minus 95 percent average d-c voltage.

It is possible to regulate the inverted voltage by grid-control from zero up to full voltage of the equipment. Arrows and polarity marks on the circuit diagram of Fig. 12 designate the voltages across the rectifier unit and d-c machine for rectifier operation and for inverter operation, which are opposite in these two cases, while the direction of current flow remains the same under all conditions since it is dependent on the inherent valve action of the mercury-arc tube.

Inversion with intermediate d-c transmission

This last-mentioned series of tests clearly proved the practicability of using mercury-arc power rectifiers for inversion and possibly high voltage transmission. In the first place, it was shown how a rectifier can be used to convert a-c power to d-c power and how the d-c power can be easily controlled for transmission purposes. In the second place, it was shown how a rectifier-inverter can be used to convert d-c power into a-c power and supply it to a three-phase, a-c system.

Even though the intermediate voltage was not very high in these tests, they nevertheless gave many valuable data applicable also to the larger problems of d-c power transmission.

By the use of mercury arc rectifier-inverters, d-c power transmission can be effected in its most flexible form. Frequency changing can be accomplished by using a rectifier to change a-c power of any commercial frequency into d-c and then using another unit at the opposite end of the transmission line to invert this d-c power into a-c of whatever frequency is desired. In general, by applying a commutating voltage of any desired frequency, within limits, the d-c power can be inverted into a-c of that frequency. It is thus possible to interconnect a-c power systems of different frequencies by means of rectifier-inverters and a d-c transmission link. One of the outstanding advantages of this type of inversion is that the frequency of neither a-c system has to be fixed; in other words, the coupling of the two systems is not rigid, but flexible within a wide range. However, it is necessary that the wattless power be taken care of by power generation equipment connected to the receiving end of the line.

Interchange of 25 and 60 cycle power

The experience gained with both small and large units prepared the way for broader applications, such as the interchange of larger blocks of power between 25 and 60 cycle systems in order to make it possible to utilize to the widest extent all existing power generation and distribution plants. A large scale application of such equipment is currently being undertaken by an industrial concern to utilize excess power available at either of two frequencies. The rating of this frequency changer is 6670 kw, interconnecting the 25 cycle power system of a midwestern steel plant with that of a 60 cycle utility system.

It is expected that the experience gained with such a flexible electronic frequency changer, making possible the utilization of available power to the utmost, may play an important part in furthering the optimum utilization of existing power resources.

STANDARDIZED FOR SAVING

Save copper! Save steel! Save man-hours! Imperative slogans these, arising out of the war crisis. Here's how the humdrum, unnoticed activities of standardization groups help achieve these goals.

R. W. Beard

TRANSFORMER DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

● Interchangeability between similar apparatus and parts has been recognized by American industry as a desirable feature for many years.

The United States Department of Commerce, in a 1921 survey, showed that 49 percent of production cost was wasted within six major industries. The Bureau of Standards undertook the work of simplification and standardization to help correct this situation. Results have been astounding.

As an example, it was found that 78 types of beds, springs and mattresses were being manufactured. The number was reduced to four. Thirty-three different sizes of hospital beds and 44 different heights were available. Now there is just one standard length, height, and width, resulting in a tremendous saving in stock, production cost, and sale price.

Another example of reducing costs and simplifying procedure is to be seen in the case of an American railroad which concluded after careful study that the number of stationery forms could be reduced from 3,789 to 679 by standardization. The early adoption of 4 ft 8½ in. track gauge as standard by American and Canadian railroads saved money and improved service.

It is difficult to imagine our highly developed American industry without standardized threads on bolts, nuts, and screws. Until 1800 no such uniformity existed. In that year Henry Maudsley, the first great toolmaker, made a revolutionary improvement in the crude metal lathe of his day by adding the slide rest and automatic screw cutting attachment. Today every hardware and 5-&-10-cent store sells highly accurate and standardized threaded parts, and no manufacturer would think of using non-standard threads in his finished product.

Early electrical industry efforts

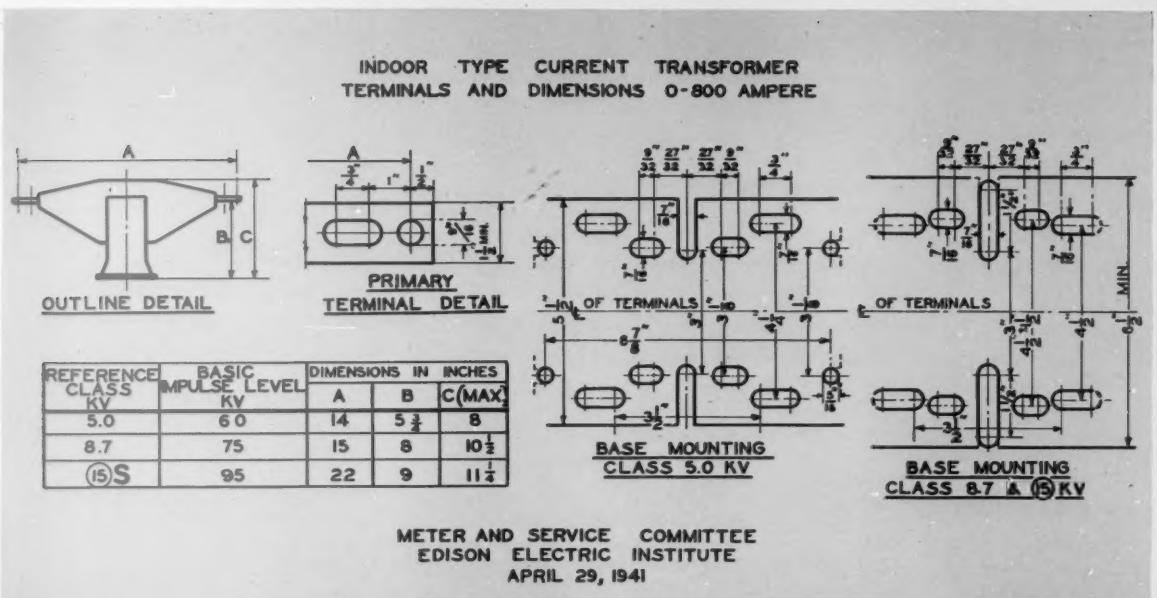
In the electrical manufacturing industry one of the first successful attempts at standardization outside of the wiring devices field took place in the watthour-meter group. Only four manufacturers were involved, thus simplifying the task of developing a standard socket in which all redesigned meters could be plugged and clamped. This standardization has been a boon to public utilities faced with the problem of testing, servicing and replacing millions of meters without costly interruption to service.

A more recent example of outstanding accomplishment in the reduction of the number of designs and elimination of waste and confusion is the work of a joint EEI-NEMA committee on the standardization of distribution transformers. In one rating alone a study indicated 14 different combinations of features could be reduced to three, with enormous improvement in service.

Indoor metering current transformers have for some years been built with uniform distance between primary bolt centers. Complete interchangeability in the dimensions of 600 volt, light-duty current transformers was accomplished about eight years ago through the joint effort of EEI and the manufacturers.

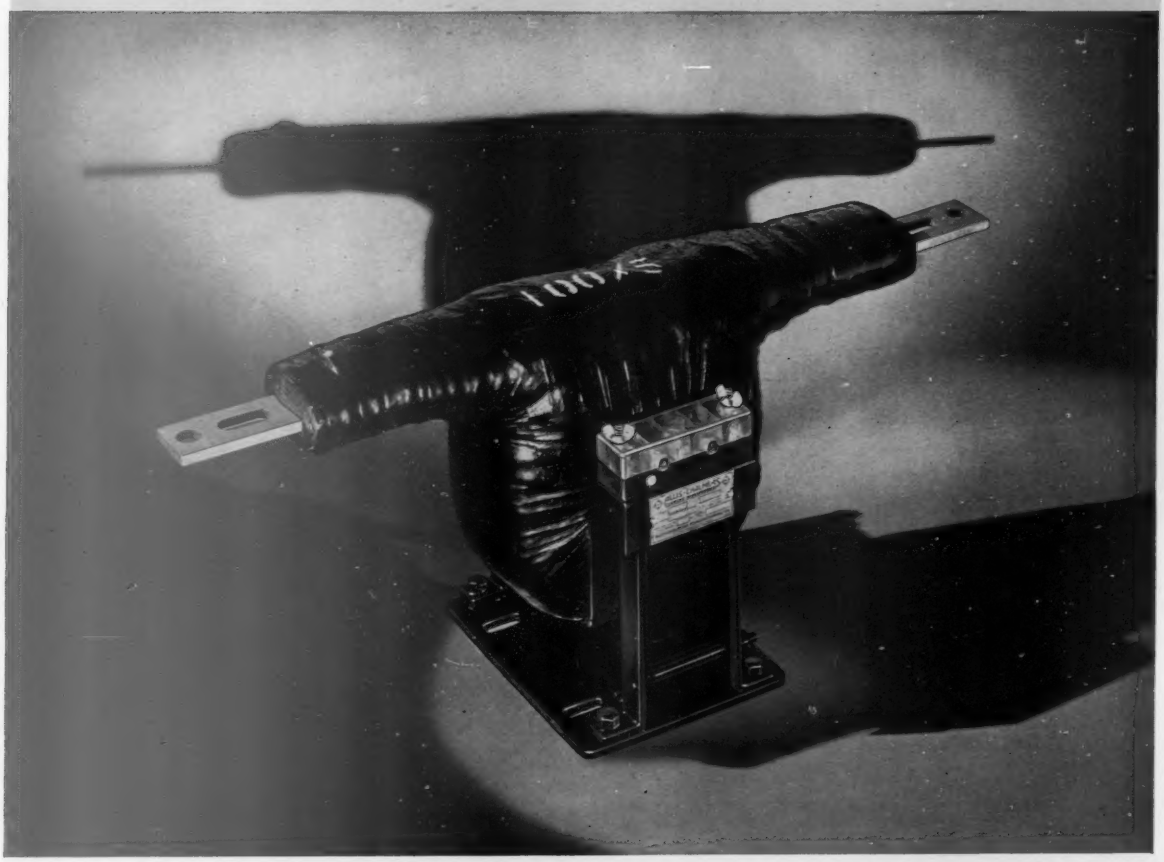
In 1938 it was suggested that an attempt be made to work out uniform dimensions for primary metering current transformers of the indoor type. A study was made in ratings 800 amperes and lower in the three voltage classes 5 kv, 8.7 kv, and 15 kv. Important data were accumulated, but no action taken at that time.

Early in 1941 the meter and service committee of EEI appointed a sub-committee for the standardization of primary metering current transformers. Information was compiled and base drilling templates made on practically all of the existing units, old or new, then in service on one of the large utilities. This work was so completely done that when a joint EEI-NEMA committee meeting was held in Buffalo in April, 1941, all of the necessary details were available for immediate action. Within two days a set of standards was established on primary terminal details, bar height and length, mounting base drillings and standard current ratings.



REFERENCE CLASS KV	BASIC IMPULSE LEVEL KV	DIMENSIONS IN INCHES A	B	C (MAX.)
5.0	60	14	5 3/4	8
8.7	75	15	8	10 1/2
(15) S	95	22	9	11 1/4

Fig. 1—Dimensions for standardized primary metering current transformers.



New standardized primary metering current transformer makes specifying and buying easier, speeds installation, simplifies stocking.

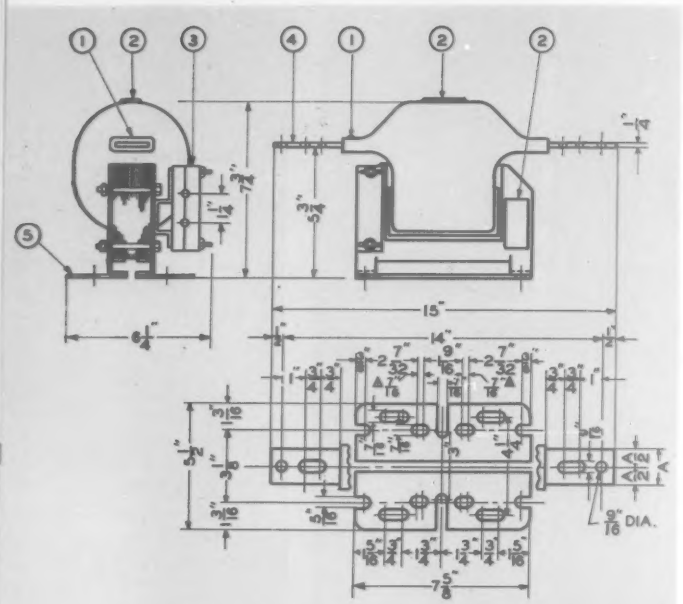


Fig. 2—Dimensions for 5 kv transformer.

Standard dimensions adopted

The speed with which a standard set of dimensions was instituted is due in no small measure to the co-operative spirit of the manufacturers in selecting the make having the most units in service as a basis for starting work.

Table I shows a comparison of the primary terminal heights before and after standardization. It will now be possible to remove a current transformer of one make or rating and install quickly another unit of different make or rating without altering the heavy primary cable or bus bars in meter boxes or on switchboards.

Manufacturer	5 kv	8.7 kv	15 kv
"A"	4 1/16	5 3/8	5 3/8
"B"	4 1/2	7 1/4	8
"C"	5 3/4	8	9
"D"	5	5	6
New Standard	5 3/4	8	9

TABLE I — Height of Primary Terminal (In.)

Interchangeability of mounting was obtained on two of the ratings by adding a plate properly punched for pipe-frame or flat surface mounting.

Figure 1 shows all dimension details. By using the same primary terminal pad with slot-hole combination on all ratings up to 800 amperes, the problem of fitting various size connectors was eliminated.

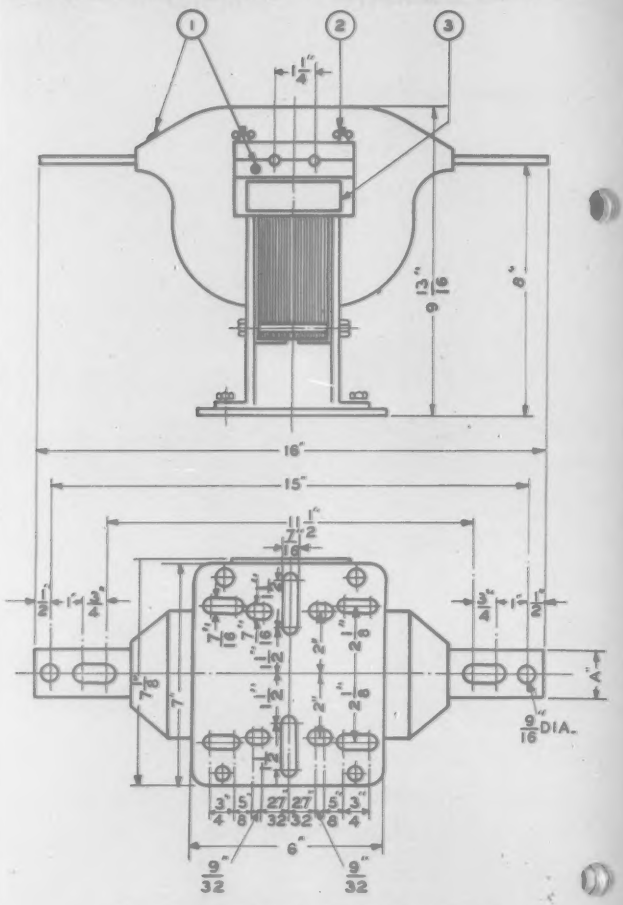


Fig. 3—Dimensions for 8.7 kv transformer.

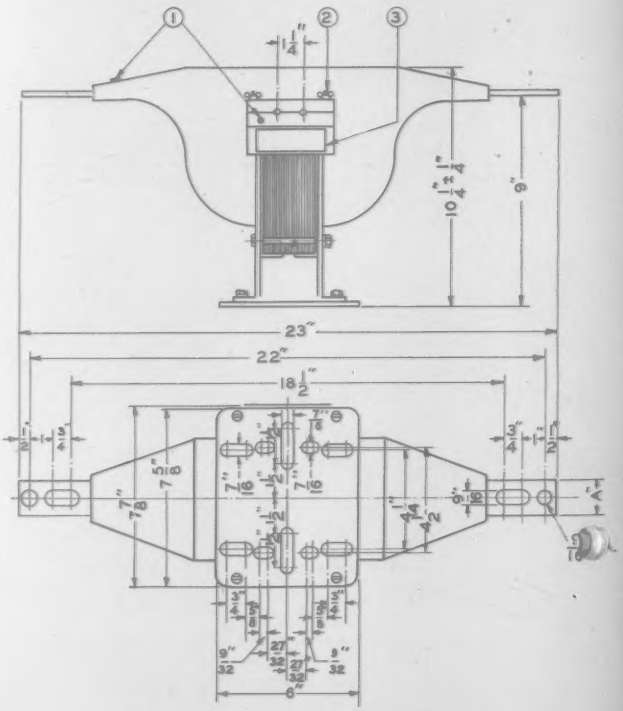


Fig. 4—Dimensions for 15 kv transformer.

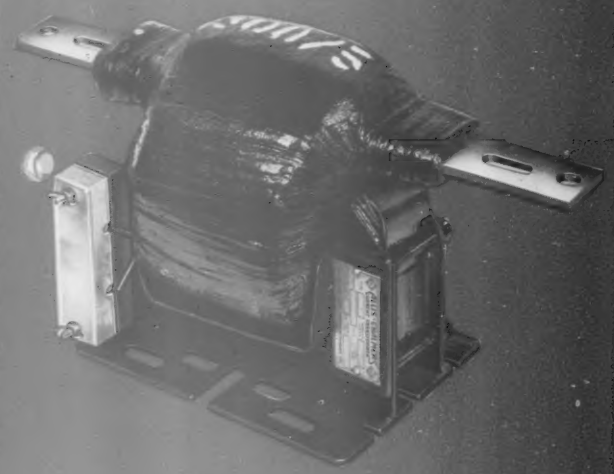


Fig. 5—Standard 5 kv transformer.

Fig. 6—Standard 8.7 kv transformer.

Fig. 7—Standard 15 kv transformer.

Standard ratings

The scope of the committee's work was extended to the subject of standard current ratings for metering purposes. One of the most important of the committee's accomplishments was the reduction of the number of recommended current ratings for billing purposes from 21 to seven. This will result in reduced inventory and better service, with an effective economy for both manufacturer and user. Table II gives the old and new listed ratings. It is recognized by the committee that complete adherence to these seven recommended ratings cannot be obtained at once, but it is generally believed that they will be ample for billing purposes. Relay and control applications will no doubt require additional ratings outside the scope of this joint committee activity.

Old List	New List	Old List	New List
5	—	100	100
10	10	120	—
15	—	150	—
20	—	200	200
25	25	250	—
30	—	300	—
40	—	400	400
50	50	500	—
60	—	600	—
75	—	800	800
80	—		

TABLE II—Primary Ampere Ratings

The final report of the committee recognizes the basic impulse levels indicated in Fig. 1. The 15 kv level marked with "S" indicates the indoor standard level. For some indoor applications a higher level of 110 kv may be required, but no uniform dimensions are available.

Great savings possible

With the completion of this standardization report, the ground work is laid for vast savings in time, effort, and expense as the various manufacturers begin production on these uniform lines.

The dimensions shown in Figs. 2, 3, and 4 represent the first designs put into production. Aside from details of processing, secondary terminal blocks and nameplates, all manufacturers' units of like ratings will be identical in important dimensions. Figs. 5, 6, and 7 show standard units for the 5 kv, 8.7 kv, and 15 kv classes.

This standardization, especially at this time when materials are precious and manpower is spread thin, should bring real savings to the industry. No longer will it be necessary to stock a wide variety of miscellaneous sizes and shapes. As pointed out previously, installation time can be greatly reduced by complete interchangeability of different sizes and makes.

Work has already been started on the extension of this standardization program to include the bar type current transformers up to 4000 amperes.

ON FOLLOWING PAGES: On cargo ships these 250 kw auxiliary turbo-generator sets, shown in various stages of assembly on the test pits, will furnish power for the lighting and control.

BLOWING TRANSFORMER RATINGS UPWARD

Blowing heat away is as instinctive as blowing at a bowl of hot soup. But blowing heat away from transformer radiators to increase capacity requires some not-so-instinctive engineering and design considerations.

K. P. Wiederkehr

TRANSFORMER DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

● A simple way to increase the capacity of a self-cooled transformer is by the addition of blowers. These are usually turned on automatically when the temperature of the oil exceeds a specified value.

Several different applications of transformers with forced air blast equipment are possible —

The first is to use the additional capacity for peak loads. During the light load cycles, the transformer will be cooled by natural air circulation only and will carry the lighter load, while during the peak load cycle additional cooling will be supplied by the forced air blast equipment, to carry the increased load.

In a second application the forced air blast equipment is used for lowering the oil and copper temperatures. In warm climates, during the period of high ambient temperature, the self-cooled transformer would not be able to carry full load continuously without exceeding the recommended temperatures. Even with ambient temperature below 40 C, forced air blast equipment may be used to secure longer life for the transformer.

A third application is the use of the forced air blast-equipped transformer to carry a larger load than its self-cooled rating for continuous operation. This permits the purchase of a smaller, and consequently less expensive, transformer than would be required if the transformer were self-cooled only.

Process of heat dissipation

An analysis of the process by which the heat in a transformer is dissipated leads to a method for determining the increased capacity which may be secured by forced cooling. The heat in a transformer due to the losses is transferred from the coils and core to the cooling oil, principally by conduction. The oil flows by convection, as shown in Fig. 1, and transfers the heat by conduction to the material of the case and radiators, from which it is transferred by radiation and conduction to the cooling air. The air is set in motion by convection, and the air currents thus set up bring new air to the surface of the radiators. Typical values of air and oil temperatures are indicated in Fig. 2.

Of the three means of heat transfer — conduction, radiation, and convection — the most important is convection. In power transformers, the quantity of heat transferred by conduction is negligible. The area effective for radiation is the outside envelope of a surface, irrespective of its shape; while the area effective for convection is the total surface area exposed to the outside air. For a transformer equipped with radiators, only a very small portion of the heat is radiated. By far the larger part is transferred by convection.

Considerable improvement in heat transfer by convection can be accomplished by forced movement of the air because the fast moving air breaks up and drives away the hot air close to the radiator surface, thereby decreasing the thickness of the air film through which the heat must flow. In addition, the average temperature of the air between the bottom and the top of the radiators is less with forced air cooling since more air moves past the surface of the radiators and its final temperature is less than that with natural convection. The curves of Fig. 2 show typical air and oil temperatures close to the radiator tubes at different radiator heights for the same transformer when operating self-cooled and when operating with forced air.

Heat transfer analysis

As will be judged from Fig. 1, the relations existing for the transfer of heat from a transformer are complex, and an exact solution is not practical. In order to simplify the problem for analysis, various approximations are necessary. By this means, combined with experimental data, a solution for practical purposes is obtained. The analytical solution obtained from the general principles involved facilitates the interpretation of the experimental data obtained from tests. Fig. 3 shows the temperature relations which are used

to derive the equations for the cooling of transformers. The direction of oil flow and air flow are shown. The distance from the bottom of the radiator is plotted along the abscissa, and temperature is plotted along the ordinate. Symbols are chosen as follows:

Y = Air temperature at any point.

Y_1 = Oil temperature at any point.

Y_2 = Air temperature when $X = X_1$.

X = Distance from bottom of radiator.

X_1 = Total height of radiator.

b = Deg C rise of bottom oil above ambient air.

b_1 = Deg C rise of top oil over bottom oil.

W = Effective watts per sq in. of radiating surface for an oil temp rise of $(b+b_1)$.

F = Cfm of air per sq in. of radiating surface.

K = Actual watts per sq in. of radiating surface per deg C.

From the geometry of Fig. 3 the following relations can be written:

$Y_1 = \frac{b_1}{X_1} X + b$, assuming straight line variation of oil temperature. The watts radiated in the distance dx and unit width = (the difference in temperature between the oil and the air) × (the radiation constant K) × (the ht of dx) $= (Y_1 - Y)\, K dx = \left(\frac{b_1}{X_1} X + b - Y\right) K dx$.

The watts absorbed by the air in the distance dx and unit width $= 0.6 \times$ (the number of cfm of air, $FX_1 \times 1$) × (the temperature rise of the air, dy) $= 0.6FX_1\, dy$. Since the heat radiated from the surface equals the heat absorbed by the air,

$$\left(\frac{b_1}{X_1} X + b - Y\right) K dx = 0.6FX_1\, dy$$

Solving this equation and substituting the value of $W = 0.6FY_2$, the final relation is obtained

$$W = 0.6F\left[\left(b - \frac{0.6Fb_1}{K}\right)\left(1 - C^{-\frac{K}{0.6F}}\right) + b_1\right]$$

The values of the quantities in the above equation depend upon the fan used, the radiator arrangement and the arrangement of the fans on the transformer. Typical curves derived from tests on typical transformers with forced air equipment are shown in Fig. 4. To apply these curves, the values of the constants for the individual transformer should be the same as the values used for the curves.

Example

The use of the curves in Fig. 4 can best be illustrated by an actual example on a transformer. Forced air equipment is to be installed on a transformer of the following rating:

Self-cooled, capacity — 20,000 kva, single-phase, 60 cycles. Temperature rise 55 C. Copper loss—76,000

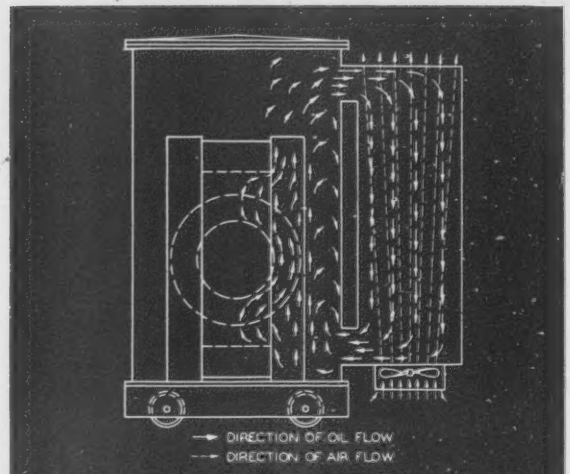


Fig. 1—Schematic diagram of oil and air flow.

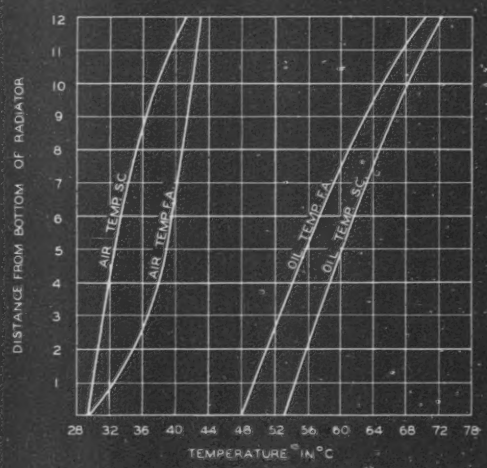


Fig. 2—Air and oil temperatures around radiator tubes—self-cooled and forced air cooled.

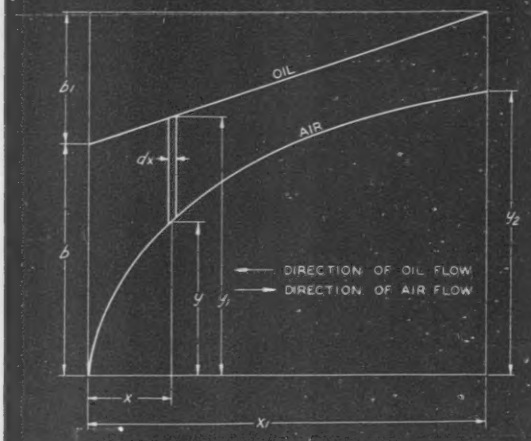


Fig. 3—Temperature relations of oil and air.

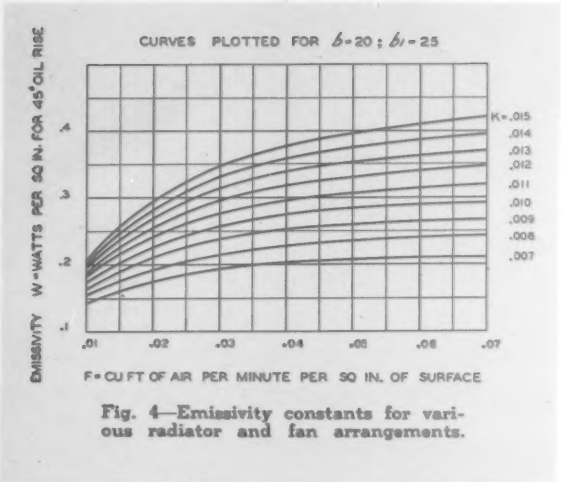


Fig. 4—Emissivity constants for various radiator and fan arrangements.

watts, core loss — 36,000 watts, total loss — 112,000 watts. Total radiating surface of both tank and radiators — 530,000 sq in. Temperature rises — top oil 48 C, copper 52 C. The capacity of the transformer shall be increased 33⅓ percent or to 26,667 kva. The loss at the forced air rating will be: for copper loss, $76{,}000\left(\frac{26{,}667}{20{,}000}\right)^2=138{,}000$ watts. Core loss, 36,000 watts, is added for a total loss of 174,000 watts. The copper over top oil rise was 52−48=4 C at full load. An approximate equation for copper over oil rise is:

$$T=(T_1+10)\times L^{1.6}-10$$

when T=gradient at load L; $L=\frac{\text{percent load}}{100}$ and T_1=gradient at full load. At 133 percent load, the copper over top oil rise will be

$$T=(4+10)\ 1.33^{1.6}-10=12.7\text{ C or }13\text{ C}$$

In order to have a copper rise of 55 C at the forced air rating, it will be necessary to have a top oil rise of 55−13=42 C. The total loss at 26,667 kva is 174,000 watts. The total radiating capacity must be sufficient so that, with a total loss of 174,000 watts, a top oil rise of not over 42 C is obtained.

$$\text{Emissivity at 42 C, } W=\frac{174{,}000}{530{,}000}=0.33$$

In order to use curves of Fig. 4, it will be necessary to convert W from the value for 42 C rise to the value for 45 C rise.

$$\text{Emissivity at 45 C oil rise}=\frac{.33\times 45}{42}=0.354$$

From tests on different blower and radiator arrangements, the proper K has been determined. K=0.013 is the proper constant for the blower arrangement in question, and a blower delivering 2,000 cfm of air shall be used. From the curve, K=0.013 in Fig. 4 and W=0.354, F=0.051, and the number of blowers required will be:

$$\text{Number of blowers}=\frac{.051\times 530{,}000}{2000}=13.5.$$

Fourteen blowers would be used.

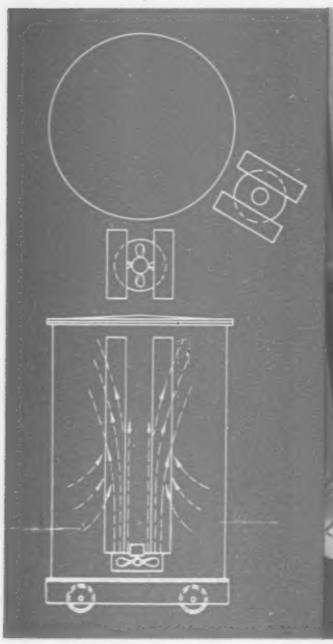


Fig. 5—One of best blower arrangements for forced air cooling of transformers.

Fig. 6 — On this installation (same as Fig. 5) blowers, located at bottom of radiator, blow air up.

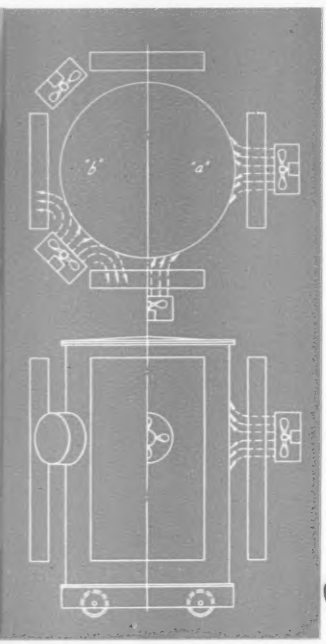


Fig. 7—Blowers can be mounted on the radiators (a) or in between them (b).

Fig. 8—Forced air fan power plug outlet.

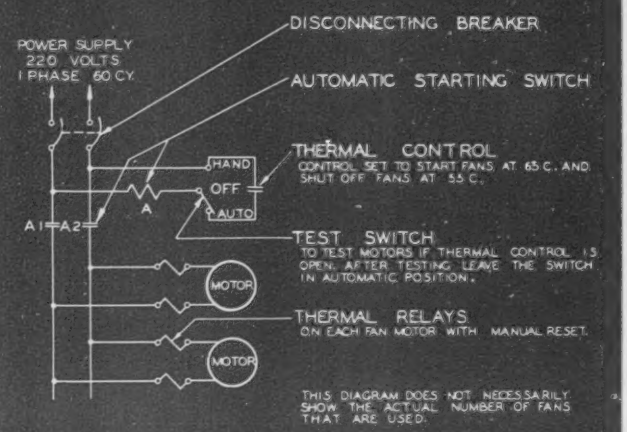

POWER SUPPLY
220 VOLTS
1 PHASE 60 CY.
DISCONNECTING BREAKER
AUTOMATIC STARTING SWITCH
THERMAL CONTROL
CONTROL SET TO START FANS AT 65 C. AND SHUT OFF FANS AT 55 C.
HAND
OFF
AUTO
A
A1
A2
TEST SWITCH
TO TEST MOTORS IF THERMAL CONTROL IS OPEN. AFTER TESTING LEAVE THE SWITCH IN AUTOMATIC POSITION.
MOTOR
THERMAL RELAYS
ON EACH FAN MOTOR WITH MANUAL RESET.
MOTOR
THIS DIAGRAM DOES NOT NECESSARILY SHOW THE ACTUAL NUMBER OF FANS THAT ARE USED.

Fig. 9—Control diagram for forced air equipment.

In applying the relations developed, it is important that experimental data on the actual blower arrangement to be used be obtained so that the proper curve may be used.

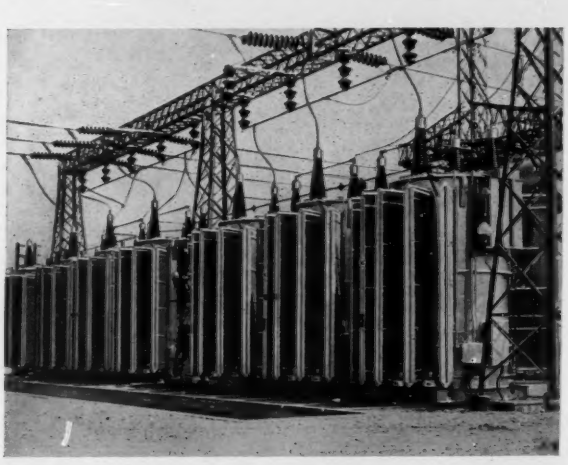
Factors affecting forced air cooling

Some of the general relatons which influence the efficiency of forced air cooling are of interest. The spacing between the radiators is determined in most cases by the spacing necessary to secure efficient cooling as a self-cooled transformer. There are many different arrangements which are possible for forced air cooling. These differ in their effectiveness.

One of the best arrangements is that shown in Figs. 5 and 6, in which the blowers are located at the bottom of the radiators and the air is blown upward. This arrangement has several distinct advantages, the most important of which are the high efficiency and the fact that the location of the blowers in between each pair of radiators does not increase the floor space required by the transformer. It permits the use of a simple propeller type fan without the use of air ducts and simplifies servicing the blower and motor from the ground level. The use of several small blowers instead of one large blower increases reliability since the loss of a single blower will not cause a loss of all forced air cooling. The arrangement of the fan with the motor on top, so that the air blows from the fan blades over the motor instead of in the opposite direction (as with conventional fans), reduces the height required for the installation of the fan unit.

Blowers as described deliver a large quantity of air at low pressure to the radiators. The air moves up between two radiators, drawing additional cool air from the outside through the lower part of the radiator tubes. The air then starts to separate, moving outward from the upper part of the radiator tubes.

With certain types of construction and arrangement of radiators, the system just described cannot be used; and an arrangement is utilized similar to that shown in Fig. 7, in which the blowers are mounted directly on the radiators as in Fig. 7a or mounted in between the radiators as in Fig. 7b, approximately one-half or two-thirds of the height of the radiator from the floor. Arrangement b requires slightly less floor space than arrangement a, but it can be used only if the radiators are spaced far enough apart to permit the location of the blower between the radiators. The arrangements in Fig. 7 are not as efficient



Installation of seven forced air cooled power transformers, rated 20,000 kva. If self-cooled, rating would be reduced to 15,000 kva.

as the one in Fig. 5, but they represent the best possible installation for this type of radiator arrangement. Numerous other arrangements of blowers are possible and are used at present; but, in general, they represent modifications of the foregoing mentioned arrangements.

Outdoor service

Blowers designed for outdoor service require special attention to design details. The motors should be single-phase, or three-phase without centrifugal switches for starting. The single-phase motor is better than the three-phase motor because it can be equipped with built-in thermostats which will open the circuit if the motor should become overloaded or if the current drawn by the motor should become excessive. Manual reset thermostats are used instead of automatic reset thermostats since, once a motor cuts out, it should not be placed in service before the motor is examined to determine whether it is in operating condition.

The loss of a single blower on a multi-blower arrangement will cause the oil temperature rise to be only slightly higher than when the blower is in service. In order to simplify installation and maintenance work on the fans, it is desirable to connect the motor by a plug and receptacle arrangement as shown in Fig. 8.

A typical control diagram for forced air equipment is shown in Fig. 9. The blowers are automatically controlled by a thermostat with its sensitive bulb located in the top oil of the transformer. When the oil temperature reaches 65 C, the thermostat closes a contact which, in turn, closes the main contactor, starting the blowers. If the oil temperature drops below 55 C, the thermostat opens its circuit, de-energizing the main contactor and shutting down the blowers. The 10 C differential, between starting up and shutting down, prevents too frequent starting and stopping of the fans.

In adding forced air equipment to existing transformers, it is necessary, of course, to calculate the new oil temperature rise with blowers running and the new copper temperature rise which will result under these conditions. In addition, the limiting factor for overloading the transformer may not be the copper of the winding but the temperature rise of the bushings or the interrupting or current capacity of tap-changing-under-load equipment associated with it. All these and similar points should be checked before applying forced air equipment to a transformer if the purpose is to carry higher overloads.

If the above factors are carefully evaluated and taken into consideration, forced air cooling may very well be utilized in some cases to meet additional wartime power requirements without drawing on the limited supplies of critical materials represented in new transformers.

New Electric Arc Furnace Control

A revolutionary, new electric arc furnace control, just announced, will greatly increase the wartime efficiency of electric furnace steel production in steel plants and foundries.

For the new furnace electrode control there has been applied the "Regulex" exciter *(extreme left in photo)*, already in use by many companies for accurate, sensitive control on temper pass and reversing mills. Extreme accuracy of the new "Regulex" control results from quick reversing and smooth acceleration, while greater production is possible with the reduction of operating troubles and maintenance.

The variable voltage control eliminates high voltage inrushes which, with the absence of contact maintenance, reduces production delays to a minimum. The new product can be expected to contribute to the rapid increase in electric furnace steel output, already doubled in the last two years.

Hot Cathode Mercury Vapor Rectifier

Recently announced is a new line of compact, self-contained hot cathode mercury vapor rectifiers which are already being purchased in large numbers by many war industries.

The units, which are sold in sizes from 1 to 15 kw for output voltages from 115 to 250 volts, are being used as power supplies for testing electrical equipment, operating small machine tools, furnishing current for magnetic chucks, searchlight power supplies, and various other applications where a simple, compact source of d-c power is required and only a-c is available.

The units are complete with incoming and outgoing line switches with overload protection, d-c volt- and ammeters, etc., and consequently do not require any additional accessories for the average application. They need no maintenance other than occasional inspection of the long-life tubes.

Used where a motor-generator set was formerly needed, these rectifiers require smaller amounts of critical copper and steel, can usually be built in a shorter time.

For further, more detailed information regarding these new products, write the Editors of ELECTRICAL REVIEW.

POWER FOR PORTLAND CEMENT
II. SELECTING PLANT EQUIPMENT*

Purchased or plant-generated power? Waste-heat or direct fuel-fired plant? Synchronous or induction motors? These are a few of the questions facing the electrical engineer in cement plant design. To answer them a working knowledge of both local conditions and cement manufacture is required.

J. M. Wolfe
CRUSHING AND CEMENT DEPT. • ALLIS-CHALMERS MANUFACTURING COMPANY

A correct selection of the source of electric power required for cement plant operation requires careful analysis. Correct selection must take into consideration availability, continuity, and cost, if the power is purchased, compared with the overall cost when power is generated in a plant operated by the cement company. Such a plant may be a direct fuel-fired steam generating plant with turbo-alternators; a waste-heat plant in which steam used to drive the turbo-alternators is generated by the high temperature waste kiln gases; or a diesel-electric station. The selection, therefore, is usually based on plant economics in which operating costs and fixed charges form the basis of comparison. Other factors, including those of plant location, must be considered; and whether the plant is located in the United States or in a foreign country plays no minor part in the final decision.

In isolated unsettled regions, such as may exist in South America, no alternative in many cases is to be found since purchased power may not be available. In such instances the plans for a cement plant must include a power plant; and, in cases of this kind, the question of power generation resolves itself into one in which the type of power plant required comprises the major issue.

In the United States the trend toward purchased power began years ago and has continued in importance because it has been found less costly to purchase power and to conserve fuel for burning the clinker by the use of major improvements in the rotary kiln which have increased its thermal efficiency. These improvements have now reached a high state of development. In existing cement plants which employ comparatively short kilns, using either the wet or dry process, the exit gas temperatures are usually high enough to permit power generation which, in most plants, provides sufficient electrical energy to operate the entire cement plant, with excess power to spare. In such cases the prevailing power rates determine whether the available heat from the kiln gases should be utilized for power generation. If the power rates are low enough, it may be economical to disregard the heat carried out by the kiln gases and waste it. The capital cost of waste-heat power plants is high; and the fixed charges, plus the additional fuel required in the kiln to which waste-heat boilers are connected, comprise the total power cost and, hence, the basis upon which the engineer must determine which type of power is the more economical.

Waste-heat power

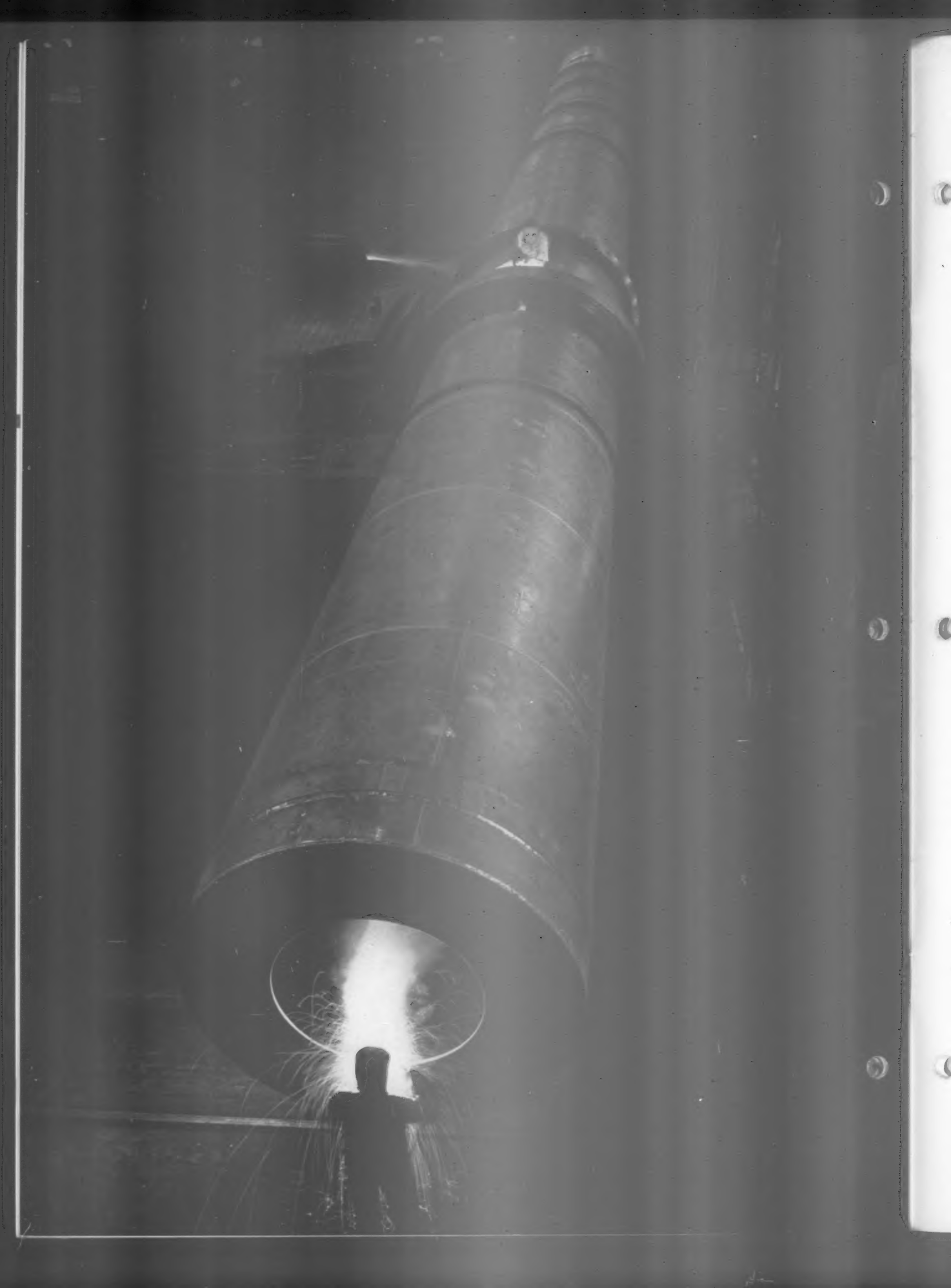
Improvements have been made to wet process kilns operating with waste-heat power by the employment of filters which reduce the moisture content in the slurry a sufficient amount to conserve fuel and, at the same time, raise the exit gas temperatures of the gases going to the waste-heat boilers. The use of filters with wet process rotary kilns is probably the most efficient type of cement plant waste-heat power generation.

Dry process kilns employing waste-heat recovery for power generation do not differ greatly in efficiency from wet process kilns employing filters and waste-heat boilers. The difference in the overall fuel economy of the two processes is slight if the plant is designed efficiently.

Wet vs dry process

During the past generation there has been a gradual shift from the dry to the wet process. This is due largely to a gradual improvement in the standards of cement and the market needs for the manufacture of several types of cement. Both of these requirements imply and need accurate blending and chemical con-

* This is the second of two articles dealing with the method of and power requirements for manufacture of portland cement.



trol of the raw materials. This control is accomplished with greater ease and precision and with less expense of fine raw material grinding when the materials are processed in a finely divided form in a mixture of water, which is called slurry.

The increased efficiency of the modern wet process kiln has so reduced the temperature of the gases leaving it that practically no heat remains for power generating purposes. To be explicit, in a modern wet process rotary kiln, equipped with an internal heat recuperating chain system, a heat recuperating clinker cooler, mechanical draft, and control instruments, the exit gas temperatures may be reduced below 400 F. This temperature is comparable with the temperature of the waste gases after leaving the economizers of a waste-heat power plant.

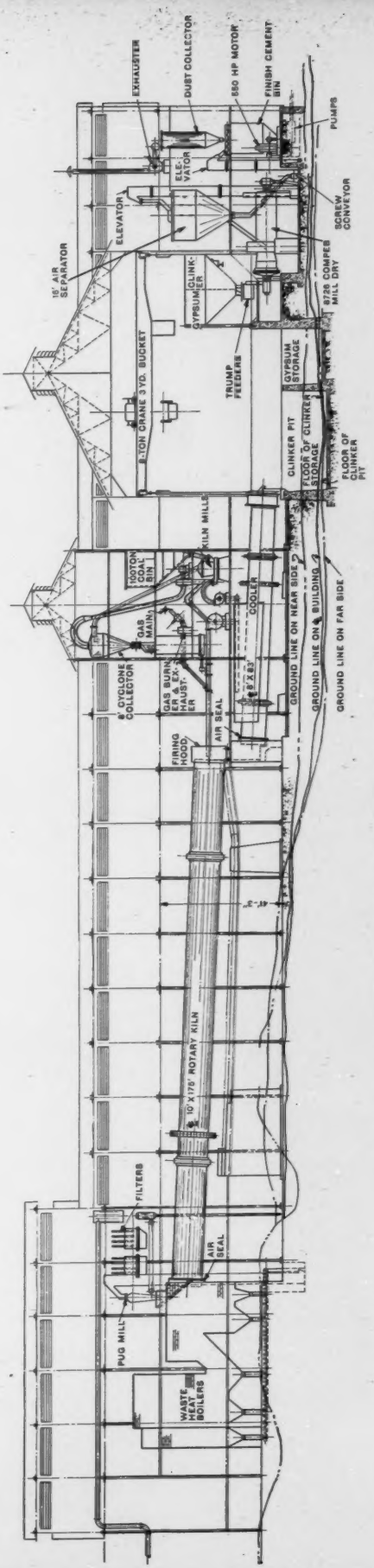
In the consideration of new cement plants to be built in the United States or any other country in which purchased power is available in sufficient quantities and at low price, it is doubtful whether waste-heat power generation will receive the consideration which it has in the past. If, however, because of war industries and their inevitable expansion, the demands for power for industrial purposes continue to increase, waste-heat power may again receive recognition.

It may be mentioned in considering the field of power generation for cement works that plant operators are confronted by problems outside the sphere of cement manufacture.

It is known that a large capital investment is required for a power generating station using either waste-heat or fuel-fired boilers. In order to keep the power costs of the cement plant at a normal rate, it is obvious that the plant should be operated at normal capacity. A waste-heat power plant, as an example, in order to realize a normal return on the investment, requires continuity of cement plant operation, which in turn depends upon a sustained market for cement.

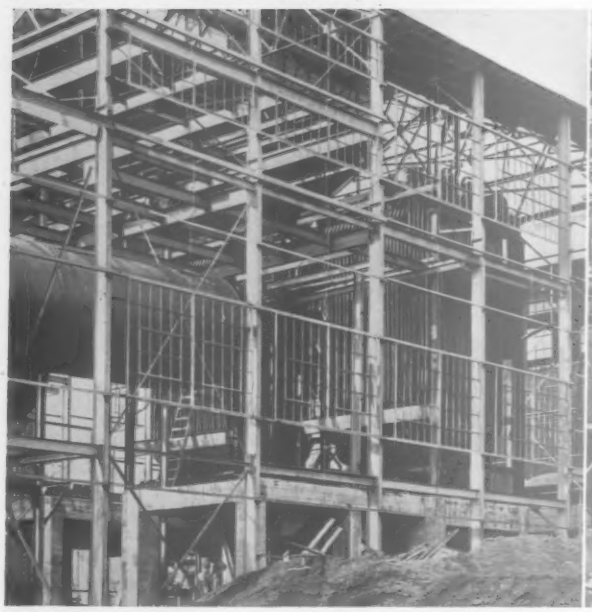
Fuel-fired power

In cases where the cement plant includes a fuel-fired power plant to generate the required power, assuming that the plant is an isolated one where market fluctuations may be a serious detriment to uniform power costs, steam turbines or diesel engines may be employed — the former with at least two fuel-fired boilers, the latter with multiple units to permit operation at high efficiency when power requirements are curtailed because of a decrease in cement output. The choice which faces the engineer in the selection of power to be thus employed is an involved one, depending upon such factors as the availability of suitable fuel oil, fresh water for steam generation or for diesel cooling, the skilled labor available, the production rat-

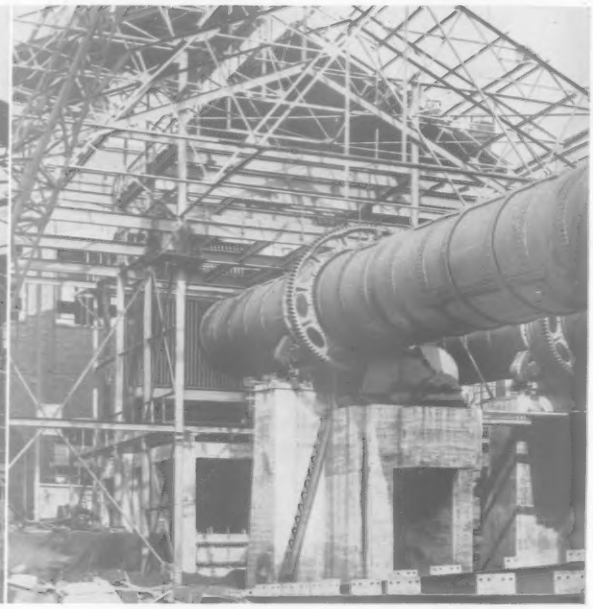


Elevation of a typical waste-heat boiler installation, showing the filters.

AT LEFT: Almost as far as the eye can see—an all-welded rotary kiln. Recent improvements in this type of equipment have meant increased plant capacity and better control of the burning process.



During the installation of this 10 ft by 175 ft rotary kiln, the water tubes for the waste-heat boilers are shown under construction.



Waste-heat boilers are located at feed end of kiln. Although capital costs are high, this type of plant often proves most efficient.

ing of the cement plant, and its likelihood of reasonable continuity of operation.

When small cement plants are considered (capacities of from 300 to 500 barrels per day), diesel-electric power seems to fulfill the requirements; but, where large blocks of power are required for higher cement production, which involves a large capital outlay for either type of power plant, the selection of power generating units depends upon local conditions. These conditions must be the basis upon which the engineer will make his final decision.

In the operation of a portland cement plant, the main purpose is to manufacture cement. This in itself is a major operating problem which involves long experience and a high degree of skill. Where large blocks of power are generated on the plant site by any of the types of power generating units mentioned previously, there is the additional burden upon the management imposed by the maintenance and operation of the power plant. The designated purpose of a cement plant is to produce cement which can be sold at a profit, and this function should not be subordinated by altering the kiln system to include equipment for the generation of waste-heat power unless the conditions are definitely indicative that it is economically sound to do so.

Trend toward smaller plants

The trend in present-day plant design is toward plants of smaller daily production. In many cases a single kiln is used. There are exceptions to this, however, notably the great plant built recently in California, near San Francisco. In this case, however, special conditions accounted for the necessity for large production. The single-kiln unit is used in many of the cement plants in this and in foreign countries, and, where the single kiln is used and waste-heat power is employed, sufficient steam cannot be generated to provide power for the entire plant unless fuel in greater quantity than that required for efficient clinker burning is introduced within the kiln or under the boiler by direct firing. In such cases an auxiliary boiler may be installed which acts as a booster and may carry a part of the plant load when the kiln is down for repairs since kiln shut-down also shuts down the waste-heat power plant.

The need for auxiliary sources of power arises because of the relatively high connected load of auxiliary equipment of single-kiln plants, the production rating of which approaches the lower limit of capacity which the auxiliaries are capable of handling. With negligible or small additions to the auxiliary machinery processing units, an additional kiln and mills might be installed to double the plant output of cement. Under such conditions sufficient waste heat would be at the disposal of the waste-heat boilers for adequate power generation except when one kiln is shut down.

A case in point is a South American plant where numerous crushers and conveyors were added to a plant employing waste-heat power. The load became excessive, and cement burning was seriously impaired. The remedy was the installation of an auxiliary boiler entirely independent of the waste-heat system. It may be generally stated, therefore, that a one-kiln plant is not suitable for waste-heat recuperation except under conditions which justify the additional capital expenditure to put in an auxiliary boiler to insure at

least partial plant operation while the kiln is down for repairs.

Motor operating conditions are rigorous

Cement plant service imposes rigorous duty on electrical equipment, particularly motors, since they often operate under extraordinary conditions of overload and in extremely dusty surroundings. The electrical apparatus, therefore, suffers from dust, abnormal loads, and often abuse at the hands of unskilled labor. Unbalanced loads, caused by crowding or congestion of the flow of materials, very often throw heavy burdens upon the motors.

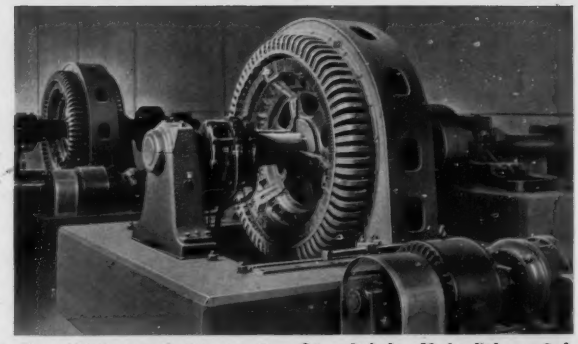
Consideration may be given to the nature of the machinery which the motors drive. These machines are jaw and gyratory crushers which shatter heavy blocks of stone; grinding mills filled with tons of steel grinding media; agitators in which slurry or clay slip of varying consistency is stirred and blended; and fluctuating loads in the kiln itself due to irregularities in the kiln operation which are the result of the wide variations in the chemical composition of the raw materials. Cement-making machinery is employed to disintegrate rocks and to calcine and subsequently to burn them to incipient fusion, after which the partially fused product is again ground to extreme fineness. It is not a delicate process.

It is not difficult, therefore, to appreciate that, where operations are carried on necessarily and continuously in dust-laden atmosphere, heat, and at times abuse, the motors may be subjected to unusual operating conditions. Far from being pampered, all types of electrical equipment are subjected to tests in a cement plant which inevitably reveal the quality of the machines and their ability to withstand the rigors of such service.

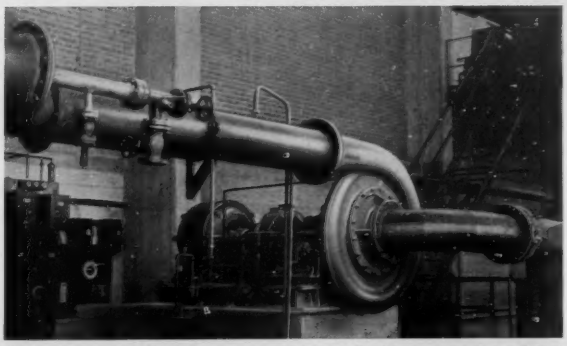
Motor selection

Cement plant motors may be classified generally in two groups: those with ratings of 100 hp and over and those of less than 100 hp ratings. The motors above 100 hp are usually wound for 2300 volts; those less than 100 hp for 440 volts. A large number of motors are designed to run under constant speed. Cement manufacture is an operation in which the several phases of the manufacturing process are interdependent to provide continuity of operation. The prime requisite of motors, therefore, is reliability. It may be necessary that they operate under conditions of prolonged overload, and their continuous operation minimizes maintenance opportunities.

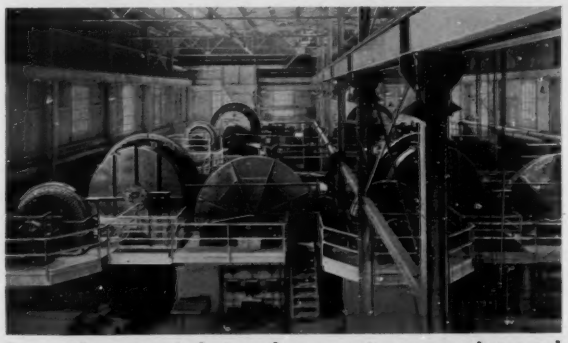
The grinding mills, which require a large block of the total plant power, are driven with motors, depending upon the size of the grinding mills, which may range from 200 to 1500 hp. The adaptation of synchronous motors for grinding mill drives is predicated on two advantages obtained by this type of motor—high efficiency and power factor correction.



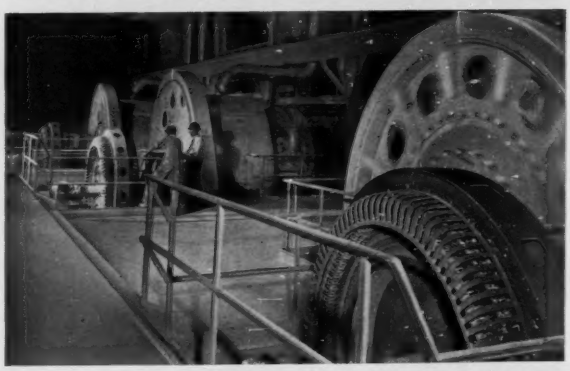
Two 300 hp synchronous motors drive 6 ft by 22 ft clinker grinding compartment mills in this South African portland cement plant.



Squirrel cage induction motor driving turbo-blower used to inject preheated primary air into oil burning equipment for firing kiln.



In a southern cement plant synchronous motors power primary and secondary wet grinding ball mills in close-circuit with classifiers.



Three dry grinding preliminators are direct-connected to two 300 hp and one 400 hp synchronous motor in a far-western cement plant.

In the first instance, the high efficiency of this motor operating under full load may result in an appreciable saving in power. The secondary benefit is an important one affecting the entire electrical installation. For these reasons the smaller motors may be selected with an ample reserve rating to meet the unusual operating conditions.

Since there are a large number of induction motors in a cement plant underloaded during normal operation, there results a low power factor which may be corrected by the large synchronous motors employed to drive the grinding mills. The type of synchronous motor selected depends largely upon the type of power available. In starting the grinding mills, a large inrush of current is drawn from the power source. This is a condition which may impose a hardship upon the power company when purchased power is used. It must be solved by agreement with the power company or by reserves in the power generating equipment if the power is manufactured at the plant site.

If the large synchronous motors are direct-coupled to the grinding mills and started "across-the-line" on full voltage, the power generating capacity must be sufficiently great to withstand the large inrush of current when the motors are started. In many instances, in order to avoid high starting currents, a magnetic clutch is employed to permit the motors to attain synchronous speed before the load is applied. The grinding mills require so large a proportion of the power used in the cement plant that it is often found practicable to design the mills of sufficient capacity to produce the complete production of the plant in sixteen hours. This allows the heavy load to be carried during off-peak periods if purchased power is employed and may result in a reduction in the power rate. When the grinding mills are shut down, if the magnetic clutch is used, the motors are idle as synchronous condensers, thus maintaining a high power factor.

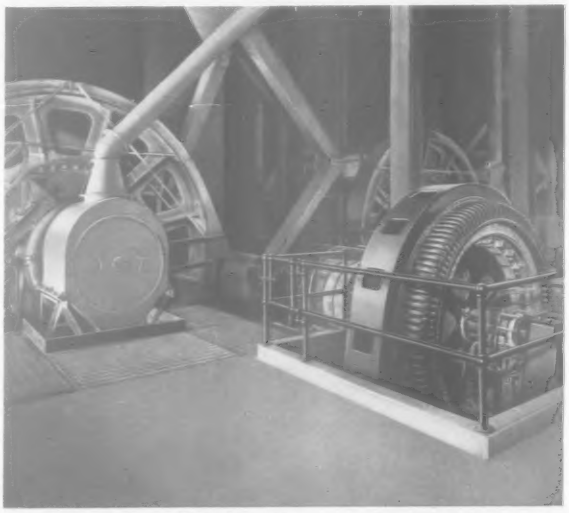
Individual analysis necessary

No fixed set of circumstances, therefore, may be applied to the design, operation, and development of more than one cement plant since each plant has its individual characteristics which the plant designer must take into consideration. The selection of electrical apparatus to fit the requisites in each case should be based upon engineering analyses made in reference to the special conditions pertaining to each case.

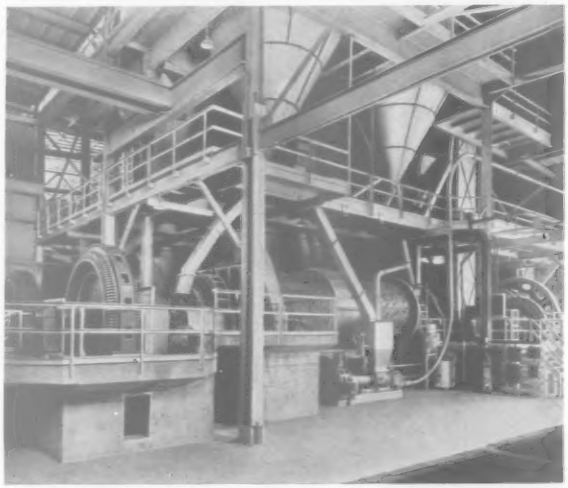
Recognition of the unique problems arising from cement plant operation and the realization that these problems must be taken into account are points that the electrical engineer recognizes when called upon to collaborate with the cement plant designer.

An important requisite toward efficiency in making appropriate recommendations for electrical apparatus, therefore, is a general knowledge of local conditions and the problems and technique employed in the manufacture of portland cement.

Induction motors drive oil pumps in a South American plant. Boiler provides steam for heater for the kiln oil burning equipment.



Direct-connected to 1000 hp, 180 rpm, unity power factor synchronous motors are two clinker grinding, four-compartment mills.



Clinker grinding preliminators and ball mills are driven by synchronous motors. Small induction motor (center) drives a cement pump.

MAKE YOUR MARK!

That maze of patent numbers seen on some patented articles is there for good reasons. For, without correct patent marking, the patentee may lose part of the protection otherwise available to him.

D. Journeaux

PATENT ATTORNEY • ALLIS-CHALMERS MANUFACTURING COMPANY

As their name clearly indicates, Letters Patent are public documents open to everyone for inspection. Anyone interested in starting to manufacture a new article is therefore able to consult, as he should, the records of the Patent Office, to determine whether the article is patented or whether it may be manufactured freely.

Frequently a manufacturer starts making articles that are already on the market, for the simple reason that it is easier for man to copy than to create; and it is unjustly that we taunt our four-handed cousins with the time-honored aphorism, "Monkey see, monkey do." If an article is sold without showing any indication that it is patented, a manufacturer desiring to copy it will be sorely tempted to assume, without investigation, that it is not patented and may be made and distributed without restriction. With some 750,000 patents now outstanding, a patent infringement search is often a formidable task and one not to be undertaken lightly.

Patented articles should be so marked

As early as 1842 Congress decided that, human nature being what it is, it should be permissible to copy unmarked articles without investigation, and passed the first statute requiring articles made under patent protection to be so marked. Under this statute and its amendments, every article patented in this country and made or sold in this country should be marked with the word "patent" and the number of the patent so as to "give sufficient notice to the public that the same is patented." (The date of the patent may be substituted for its number if the patent issued before April 1, 1927.) The marking may be applied to the package containing one or more articles if the article itself is of such character that it cannot be marked.

In former years the penalty for failing to apply the proper patent marking used to be a fine. At present, however, the patentee neglecting properly to mark his patented articles is merely prevented from recovering damages caused to him by infringement of his patent, unless the infringer continues his invasion of the patentee's rights after being duly notified of his infringement.

Conversely, it is a criminal offense punishable by a fine to mark an unpatented article as being patented, but only if this is done "for the purpose of deceiving the public." Thus, when there is no intent to deceive, placing a patent marking on an unpatented article is condoned, a fortunate circumstance for manufacturers who have to keep straight the markings of different kinds of patented and unpatented articles.

Even articles on which the patent has expired may, with impunity, bear a patent marking if it appears that this was not done to deceive the public. In 1876, sewing machines of a popular make were marked with the dates of several patents, including the one shown in Fig. 1, which had all expired at that time. Apparently this marking had been initiated during the life of the patents and carried through past their expiration, and it was held in 1882 that no intention was apparent to represent the machines as still being patented.

Patent marking is required on articles made under design patents as well as mechanical patents, but should not be confused with copyright marking. Lack of patent marking does not render a patent invalid, while lack of copyright marking precludes the securing of copyright protection.

Articles should be marked plainly

The language of the marking statute is simple enough; but, as with all laws, the bewildering variety of unforeseen circumstances under which it was applied caused the courts to investigate its requirements in many litigations in which it was invoked. For example, since the purpose of patent marking is to give

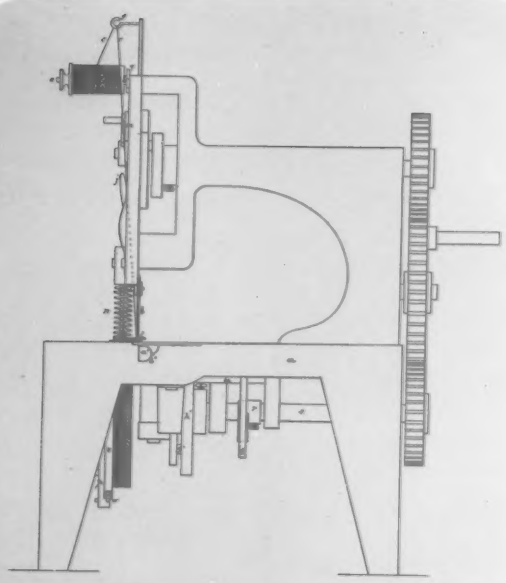


Fig. 1—I. M. Singer's sewing machine, patented in 1851. The manufacturer was held not guilty of false marking in continuing to mark the machines after the patent expired.

notice to the public, it would seem clear that the articles should be marked plainly.

This was evidently overlooked by a manufacturer of a patented looseleaf binder having a metal plate slipped into the thickness of a leather back, as shown in Fig. 2. The number of the patent was marked on the binder in characters so small as to be readable only with the aid of a magnifying glass, for the reason that larger characters would have defaced the binders. The law, however, is not concerned with defacing patented articles, and in 1931 a court found the marking on the binders to be deficient.

Mark article itself if possible

That the patented article itself must be marked whenever feasible also needed to be emphasized by a judicial condemnation of relevant examples. One such was a cherry stoner of the type shown in Fig. 3, which was sold with a tag attached to it bearing the patent marking, a practice condemned in court in 1913. Another was the patented wooden dish shown in Fig. 4. The dishes were packed in crates which bore the patent marking. In 1893 this marking was held improper because the dishes were susceptible to marking. No weight was given to the pretty transparent excuse, and an afterthought to boot, that individually marked dishes would be so expensive as to be uncompetitive.

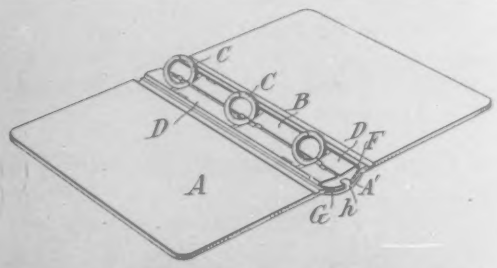


Fig. 2—C. D. Trussell's binder, patented in 1912, was improperly marked with the number in microscopic characters.

Marking package sometimes permissible

Whether or not it is feasible to mark the article itself instead of its packages is not always beyond question. The Supreme Court itself felt bound to recognize that, in doubtful cases, something must be left to the judgment of the patentee although it would be unwise to assume too much latitude in that respect. It is true that in 1892 this Court held small trunk catches of the type shown in Fig. 6 adequately marked by affixing a patent marking label to the package in which the catches were shipped and sold. But that was a long time ago, and the Court may well reverse itself some day, as it sometimes does, in view of the present state of perfection of marking devices.

In the meanwhile, it was held in 1932 that the popular razor shown in Fig. 5 was properly marked by marking its package. It is difficult to see why marking the razor itself should have been fraught with insurmountable obstacles, especially as the court remarked that nothing requires every element of a patented combination to be marked separately.

It should be clear from the statute that no patent marking is adequate if it is not applied to the patented article or to its container. As late as 1909, however, the owner of a design patent on the hat band shown in Fig. 7 had to find that out the hard way. The patented bands were applied to ladies' sailor hats in whatever eccentric manner was then dictated by fashion, and the patent marking was carried on the lining of the hat. This marking was held improper. While it would have been unreasonable to require that the hats be worn showing the word "patented" in large letters on the band, there were other proper ways of applying the marking.

Multiple patent marking

It often happens, especially in the case of complicated machinery, that a manufacturer owns several patents covering different features of a particular article. To comply with the spirit of the statute, the marking should include the number of every patent having a claim reading on the article. Besides, this is necessary to enable the patentee to recover all damages he suffers by infringement of any of the patents.

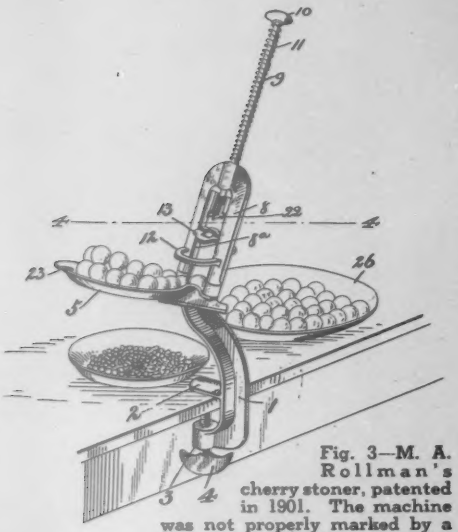


Fig. 3—M. A. Rollman's cherry stoner, patented in 1901. The machine was not properly marked by a tag tied to it and bearing the patent number.

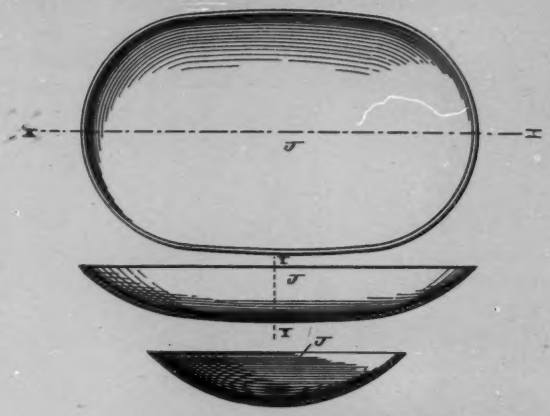


Fig. 4—S. H. Smith's wooden dish, patented in 1883. Applying the patent marking to the crate enclosing the dishes was held improper.

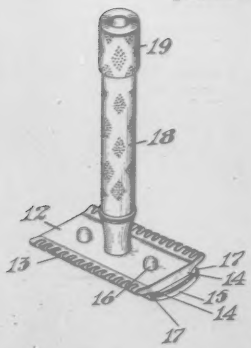


Fig. 5—R. E. Thompson's razor, patented in 1931, was properly marked by indicating the patent number on its package.

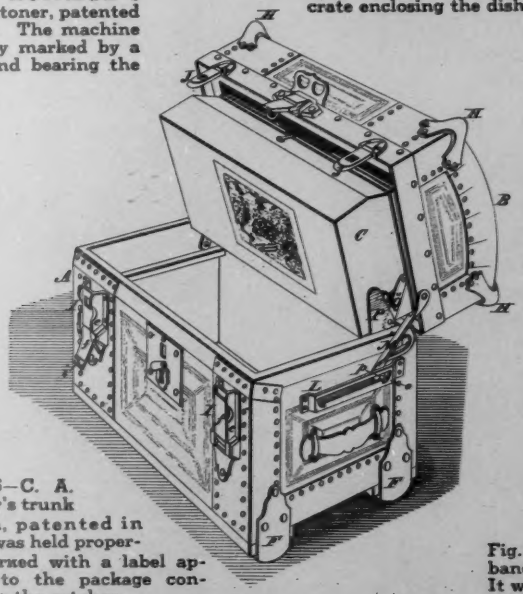


Fig. 6—C. A. Taylor's trunk catch, patented in 1872, was held properly marked with a label applied to the package containing the catches.

Fig. 7 — Lichtenstein's hat band design, patented in 1907. It was held improper to apply the number of the patent to the lining of the hat.

Fig. 8—Patent plate for different articles all covered by one or more of a group of patents.

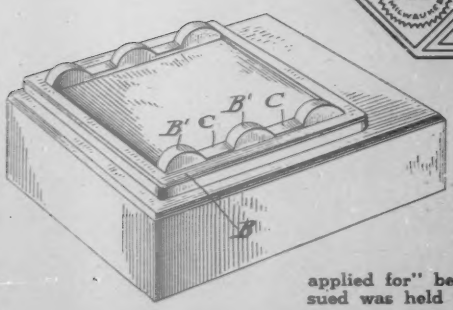


Fig. 9—F. M. Ashley's inkstand design, patented in 1912. The marking of "Patent applied for" before the patent issued was held to be of no effect.

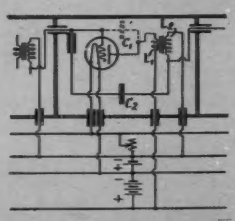


Fig. 10—L. A. Hazeltine's radio receiver circuit, patented in 1925. The patent owners were held responsible for failure of their licensees to comply with statutory marking requirements.

When it is doubtful whether several patents all apply to a particular article, everything is to be gained by listing them all. For this purpose, and also for simplifying the procedure of marking a wide variety of articles, many manufacturers use blanket patent plates, such as the plate shown in Fig. 8, to be fastened to all articles coming under any of the patents listed.

Marking patent pending

The much abused Pat. Pending, which is not the name of an Irish inventor, is often used as a bugaboo to frighten prospective imitators of unpatented articles but is of doubtful standing. The equivalent marking "Patent applied for" on the inkstand shown in Fig. 9 was disposed of in court in 1915 with the remark that it was not in strict accordance with the language of the statute. On the other hand, another court held more recently that loose-leaf books on which a patent application was pending should have been so marked. Such conclusion was probably unreasonable, but until the Supreme Court so decides it will be safer to mark articles on which a patent is pending.

Every one of patented articles must be marked

One requirement which some patentees have failed to observe is that a definite attempt must be made to mark every one of the patented articles, no matter how few or how numerous they may be. Accidental failure to mark a few articles out of hundreds of thousands may be excused. But the exclusive licensee of the patent on a machine for making finned radiator tubing was found to have shirked his duty for having, in a room barred to the public, three unmarked machines located next to two machines that were properly marked.

Also, any party bringing suit against an infringer is held responsible for seeing that patented articles made by his licensees be marked as if he had manufactured them himself. This requirement probably came as a surprise to the owners of the patent on the once popular radio receiver circuit shown in Fig. 10, who were denied recovery in 1937 because their licensees had marked only two-thirds of the radio sets made under the patent.

Regardless of circumstances, and although there is no immediate or degrading penalty for failing to mark a patented article, the cost of marking it must be considered as a good investment if recovery for patent infringement is important. Although the value of marking may not be apparent at the time and the inclination may be to apply it casually, the headaches of negligent patentees are evidence that patent marking is often one of those little things that count, and should be done well.

Question—We have an old 5000 kva, 6600 volt turbo-generator that has been out of service for about nine years. It becomes necessary to put it back on the line. What precautions should we take in regard to insulation?

Answer—The winding should be carefully inspected for deterioration, and all dirt removed with a compressed air stream or cloth dampened with a suitable cleaning fluid. If the winding is physically sound, it should be dried at about 75 C until insulation resistance becomes constant. Drying can be done in one of three ways: (1) External heat source and blower, (2) passing d-c through winding, or (3) running generator with stator short-circuited. The minimum safe dry resistance for a generator of this rating at 75 C is 6.3 megohms for the stator and one megohm for the rotor.

High insulation resistance does not insure freedom from damage; hence it may be desirable to test phase-phase and phase-ground insulation with about 8200 volts for one minute. Then several coats of a good air-dry insulating varnish should be applied.

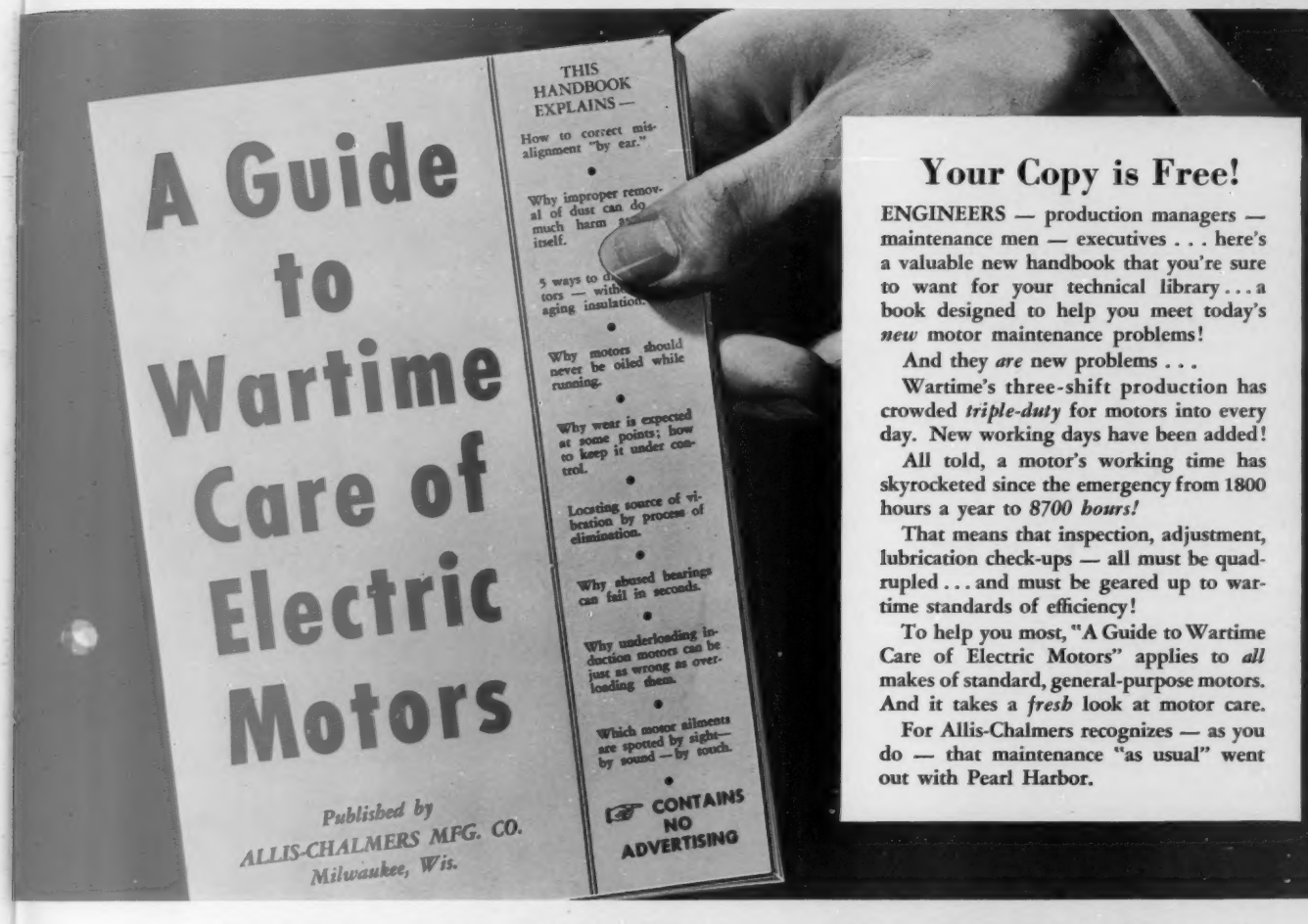
Question—In large motor and synchronous condenser construction what determines which is better, ring-oiling sleeve bearings or flood-lubricated bearings with an oil pump and cooler?

Answer—In small machines, the heat generated in bearing losses can be readily dissipated by radiation and convection without overheating. In large machines the quantity of heat developed in bearing losses is so large that flood lubrication is required to carry it away. Oil rings are used in addition to flood lubrication to protect the bearing in case of failure of oil supply.

"What's the Answer?" is conducted for the benefit of readers of ELECTRICAL REVIEW who have questions on central station, industrial or power plant equipment. Send all questions to the Editors of ELECTRICAL REVIEW.

Announcing

A VITAL NEW AID TO VICTORY PRODUCTION . . .


A Guide to Wartime Care of Electric Motors
Published by
ALLIS-CHALMERS MFG. CO.
Milwaukee, Wis.
THIS HANDBOOK EXPLAINS —
How to correct misalignment "by ear."
Why improper removal of dust can do much harm itself.
Why motors should never be oiled while running.
Why wear is expected at some points; how to keep it under control.
Locating source of vibration by process of elimination.
Why abused bearings can fail in seconds.
Why underloading induction motors can be just as wrong as overloading them.
Which motor ailments are spotted by sight—by sound—by touch.
CONTAINS NO ADVERTISING

Your Copy is Free!

ENGINEERS — production managers — maintenance men — executives . . . here's a valuable new handbook that you're sure to want for your technical library . . . a book designed to help you meet today's *new* motor maintenance problems!

And they *are* new problems . . .

Wartime's three-shift production has crowded *triple-duty* for motors into every day. New working days have been added!

All told, a motor's working time has skyrocketed since the emergency from 1800 hours a year to *8700 hours!*

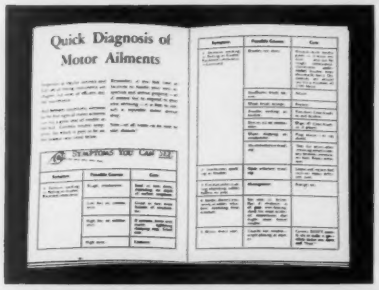
That means that inspection, adjustment, lubrication check-ups — all must be quadrupled . . . and must be geared up to wartime standards of efficiency!

To help you most, "A Guide to Wartime Care of Electric Motors" applies to *all* makes of standard, general-purpose motors. And it takes a *fresh* look at motor care.

For Allis-Chalmers recognizes — as you do — that maintenance "as usual" went out with Pearl Harbor.

Send for this Valuable new Handbook today

COMPLETELY ILLUSTRATED — Making principles of motor care crystal clear. Of particular value for training new men.



HANDY REFERENCE — Helping you catch motor troubles at early stage. Tear out order form and send for *your* free copy!

TEAR OUT THE SELF-MAILING REPLY CARD HERE.

★ ★ ★

FILL IT OUT *TODAY* AND MAIL FOR YOUR *FREE* COPY!

ALLIS-CHALMERS

MILWAUKEE · WISCONSIN

WE WORK FOR VICTORY WE PLAN FOR PEACE

How to get FASTER, EASIER, SAFER Industrial Expansion!

INSTALLED RIGHT AT the machine they serve, Allis-Chalmers Dry Type Transformers, like this 37½ kva unit, eliminate long secondary runs of heavy copper . . . improve voltage conditions.

Allis-Chalmers Dry Type Transformers Can Be Installed Right at Load Centers . . . with No Fire Hazard . . . No Time-Wasting Vault Construction . . . No Long Runs of Secondary Copper!

Now is the time America at war must do everything possible to speed industrial expansion and conversion. And one way more and more plants are doing this . . . and at the same time getting increased production . . . is with Allis-Chalmers Dry Type Transformers.

HERE'S WHY—

1. No Fireproof Vaults! Absence of oil eliminates need for time-wasting construction.

2. Save Valuable Floor Space! Allis-Chalmers Dry Type Transformers can be placed anywhere — on posts, beams, overhead platforms—because there's nothing to leak.

3. Greater Flexibility! Smaller transformers at load centers permit quick changeover to meet shifting production demands.

4. Conserve Vital Copper! Long, heavy secondary runs are done away with . . . savings in copper run as high as 50%!

5. Improved Motor and Lamp Performance! On-the-spot location means you need less voltage regulation. And your line losses are lower.

6. Maintenance Slashed! Your servicemen don't have to waste time testing or filtering insulating liquids.

For complete information on the Allis-Chalmers Dry Type Transformer, call the district office near you. Or write direct to Allis-Chalmers, Milwaukee, Wisconsin.

A-1522

ALLIS-CHALMERS
MILWAUKEE-WISCONSIN

WE WORK FOR VICTORY WE PLAN FOR PEACE